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VALUE CREATION IN ELECTRIC VEHICLE CHARGING NETWORKS

Master's Thesis
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Abstract of master's thesis

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Abstract

Electric vehicles (EV) are gaining a prominent share of the trillion-dollar automotive market. The growth is fueled by falling battery prices, tightening emission standards, government subsidies and increasing competition. The rise of EV's creates a need for, and also depends on, charging infrastructure on a large scale.

Electric vehicle charging networks are services that are used to manage and enable access to charging points. This study aims to understand how these networks can succeed in the tightening competition by examining what factors contribute to the value of an EV charging network for its participants.

To reach this goal an explanatory single case study was conducted. The case examined a public EV charging network in Finland. First, earlier research in platform economics and EV charging were used to understand the context and to synthesize a theoretical framework. Next, empirical data was collected primarily with semi-structured interviews. Finally, pattern matching was used to analyze the data.

Based on the results, the EV charging industry is still its infancy. EV charging networks mediate transactions between EV drivers and charging point owners (CPO), enabling exchange of information, control of charging points, and payments. Various signals suggest an expansion towards the energy system, as EV charging networks are likely to start aggregating and mediating vehicle-to-grid (V2G) services between EV drivers and energy market agents.

The results suggest two focus areas as key factors creating value for participants. Firstly, the main contributor to the success of an EV charging network is the amount of charging points connected to it. This is mainly due to EV drivers' strong positive cross-side network effects and to CPOs' strong positive same-side network effects.

Secondly, an EV charging network's boundary resources should be designed to maximize efficiency for both sides. For EV drivers, charging is a mundane task that needs to be as effortless as possible. For CPO's, offering charging is not a main business, but a relatively small value-added service.

This study serves as a starting point for a new research stream, converging EV charging with platform economics research. In addition, the results help researchers in understanding the state of the industry and network operators in making strategic decisions.

Keywords boundary resources, charging point owner, electric vehicle, electric vehicle charging, electric vehicle charging network, electric vehicle driver, multi-sided platform, network effect, platform, platform architecture, platform economics, vehicle-to-grid

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Tiivistelmä

Sähköautot ovat saavuttamassa merkittävän osuuden biljoonan dollarin automarkkinasta. Kasvua kiihdyttää akkujen hintojen lasku, tiukentuvat päästörajoitukset, julkiset tuet sekä koveneva kilpailu. Sähköautojen määrän kasvu luo tarpeen, ja myös perustuu, laajamittaiselle latausinfrastruktuurille.

Sähköautojen latausverkostot ovat palveluita, joilla latausinfrastruktuuria hallitaan ja sen käyttö mahdollistetaan. Tämä tutkimus pyrkii ymmärtämään, kuinka nämä verkostot pystyvät menestymään kovenevassa kilpailussa tutkimalla tekijöitä, jotka vaikuttavat verkoston arvoon sen eri osapuolille.

Tavoitteeseen pääsemiseksi toteutettiin yksittäinen tapaustutkimus. Tutkimus tarkasteli julkista latausverkostoa Suomessa. Ensiksi, aiempia tutkimuksia alustataloudesta ja sähköautojen latauksesta käytettiin teoreettiseen viitekehykseen. Seuraavaksi dataa kerättiin ensisijaisesti kahdenvälisillä tapaustutkimushaastatteluilla. Lopuksi dataa analysoitiin vertaamalla sitä teoreettisiin ehdotuksiin.

Tulosten perusteella sähköautojen lataus on toimialana vielä lapsenkengissään. Latausverkostot välittävät transaktioita autoilijoiden ja latauspisteiden omistajien välillä, mahdollistaen tiedonkulun, latauspisteiden kontrollin ja maksamisen. Useat signaalit esittävät, että verkostojen toiminta laajenee energiajärjestelmää kohti, sillä latausverkostot alkavat todennäköisesti aggregoimaan ja välittämään vehicle-to-grid (V2G) –palveluita sähköautoilijoiden ja energia-alan toimijoiden välillä.

Keskeisimpinä arvoa lisäävinä tekijöinä tulokset ehdottavat kahta painopistealuetta. Ensinnäkin, keskeisin myötävaikuttaja sähköautojen latausverkostojen menestykseen on siihen yhdistettyjen latauspisteiden määrä. Tämä johtuu pääasiassa sähköautoilijoiden voimakkaasta positiivisesta toispuoleisesta verkostovaikutuksesta sekä latauspisteiden omistajien voimakkaasta positiivisesta samanpuoleisesta verkostovaikutuksesta.

Toiseksi, sähköautojen latausverkoston rajaresurssit pitää suunnitella siten, että tehokkuus maksimoidaan molemmilla puolilla. Sähköautoilijoille lataus on arkipäiväinen rasite, jonka pitää olla niin vaivaton kuin mahdollista. Latauspisteiden omistajille lataus ei ole päätoimiala, vaan verrattain pieni lisäarvopalvelu.

Tämä tutkimus toimii lähtöpisteenä uudelle tutkimusalueelle, joka yhdistää alustatalouden ja sähköautojen latauksen. Lisäksi tulokset auttavat tutkijoita ymmärtämään toimialan kehitystä ja latausverkostoja tekemään strategisia päätöksiä.

Avainsanat alusta, alustatalous, alusta-arkkitehtuuri, latauspisteen omistaja, monipuoleinen alusta, rajaresurssit, sähköauto, sähköautoilija, sähköauton lataus, sähköauton latausverkosto, verkostovaikutus, vehicle-to-grid

Acknowledgements

The ecosystem around electric vehicles is fantastic. The excitement around the new technology and the feeling of working towards a cleaner future make the community close-knit. This thesis is a reflection of this community - individuals from various backgrounds coming together to boost the transition towards clean transportation.

Everyone in the ecosystem deserves credit for bearing the pain of an early adopter. Special thanks to the individuals who dedicated their time for the sake of this thesis: the EV drivers, the charging point owners, and especially the network operators.

This community wants to believe in a better future. The story behind this thesis is best told by the former Governor of California Arnold Schwarzenegger (2015):

"*There are two doors. Behind Door Number One is a completely sealed room, with a regular, gasoline-fueled car. Behind Door Number Two is an identical, completely sealed room, with an electric car. Both engines are running full blast.*

I want you to pick a door to open, and enter the room and shut the door behind you. You have to stay in the room you choose for one hour. You cannot turn off the engine. You do not get a gas mask.

I'm guessing you chose the Door Number Two, with the electric car, right? Door number one is a fatal choice - who would ever want to breathe those fumes?

This is the choice the world is making right now.

To use one of the four-letter words all of you commenters love, I don't give a damn if you believe in climate change. I couldn't care less if you're concerned about temperatures rising or melting glaciers. It doesn't matter to me which of us is right about the science.

I just hope that you'll join me in opening Door Number Two, to a smarter, cleaner, healthier, more profitable energy future."

Abbreviations

AC	Alternative current
BEV	Battery electric vehicle
CPM	Charging point manager
CPO	Charging point owner
DC	Direct current
DSO	Distribution system operator
EV	Electric vehicle
EVCN	Electric vehicle charging network
EVSA	Electric vehicle supplier-aggregator
EVSE	Electric vehicle supply equipment
ES	Energy system
GHG	Greenhouse gas
ICE	Internal combustion engine
MSP	Multi-sided platform
PHEV	Plug-in hybrid electric vehicle
RFID	Radio-frequency identification
SA	Supplier
TSO	Transmission system operator
V2G	Vehicle-to-grid

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1 Introduction

Because of the energy efficiency and environmental advantages over traditional transportation methods, the future of electric vehicles (EV) is promising (EPRI and NRDC, 2007). The rise of EV's creates a need for, but also depends on, charging infrastructure on a large scale. This infrastructure - a network of charging devices - is in most cases managed through a digital service.

This thesis investigates value creation in EV charging networks. In addition, there is a need to understand key participants, their roles and interactions in the network. The conducted research relies on platform economics theory from information systems research and on electric vehicle charging research from various fields. Earlier research is applied in a single case study that aims to explain how EV charging network operators can succeed in creating value for participants.

This introductory chapter starts with an overview of the context and motivations for the study. Next, the research approach is introduced. Finally, the overall structure of this report is presented.

1.1 Background

Transportation on roads is a key element in the modern society as it enables the free movement of goods and people (Rautiainen, 2015). It is also a major consumer of energy, and most of the consumption is fueled purely by petroleum (Davis et al., 2014).

The amount of oil available is continuously decreasing while demand is increasing. This increased demand together with increasing uncertainties in production cause economic challenges, e.g. slowing down growth (Partanen et al., 2015). EV's can be used to reduce dependency of imported oil, thus improving trade deficits in most Western countries.

At the same time climate change poses a significant threat to humanity on a variety of fronts. In the Paris Climate Agreement, negotiated in 2015, a total of 195 United Nations Framework Convention on Climate Change member states agreed to work on keeping the global average temperature increase below 2 °C (UN, 2015). In order to stay below this limit, greenhouse gas (GHG) emissions would need to be reduced first by 40-70 % by 2050 from the 2010 level, and then to a zero or negative emission level by 2100

(IPCC, 2014). Unfortunately, the amount of global GHG emissions has increased during this decade (IPCC, 2014), but the Paris Agreement gives hope.

Road transportation accounts for 27 % of global GHG emissions (IEA, 2013), so EV's can contribute significantly to lower emissions levels, but only if the electricity being used is de facto produced using clean production methods. In addition, with no local emissions, EV's can contribute to air quality and noise pollution improvements in big cities (Choi et al., 2013; Holtsmark & Skonhoft, 2014).

Electrification of transportation is moving fastest in the passenger car sector. The growth has been fueled by falling battery prices, tightening emission standards, government subsidies, and also recently by increasing competition. While it is hard to estimate the exact growth of EV's, there is one thing most analysts agree on: reaching price parity with internal combustion engine (ICE) vehicles will create an inflexion point for demand. Depending on the study this is expected to happen between 2018-2025 (Bloomberg New Energy Finance, 2017; Campbell, 2017).

There are two major EV adoption barriers. Firstly, EV's have a relatively high price tag, which is mainly caused by significantly expensive batteries (e.g. Brownstone et al., 2000; Luo et al., 2014; Nykvist & Nilsson, 2015). Fortunately, battery prices are expected to drop considerably as economies of scale kick in (Nykvist & Nilsson, 2015). This phenomenon is visible in Figure 1.

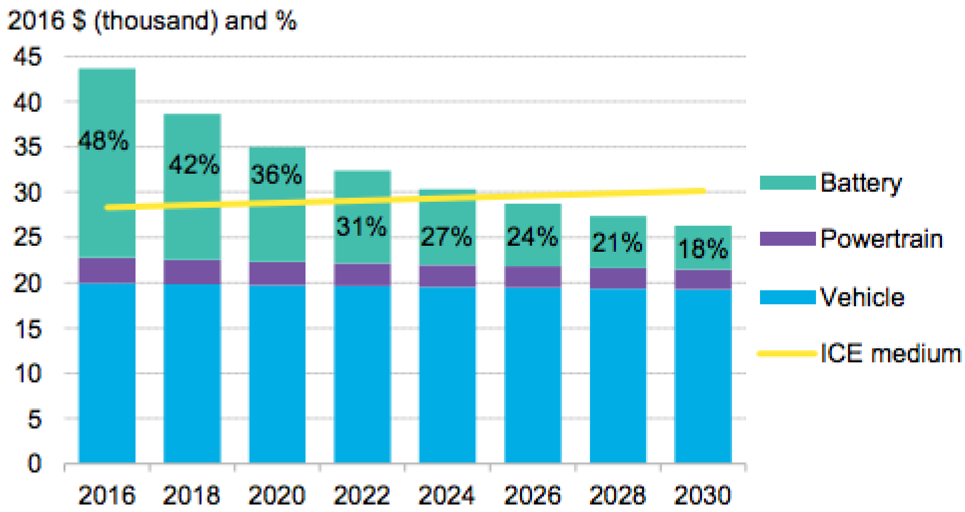

Figure 1. A breakdown of EV price components compared to ICE medium price (Bloomberg New Energy Finance, 2017)

Secondly the lack of sufficient charging infrastructure is affecting consumer behavior negatively. The availability of charging points is an important determinant in consumer acceptance of EV's (e.g. Struben & Sterman, 2008; Egbue & Long, 2012; Tran et al., 2012). To tackle this challenge the European Union has obligated member states to build sufficient public charging networks (EU, 2014). As an important rule of thumb, EU dictated that there should be at least one public charging point for ten EV's.

From the end user's perspective, the biggest change with EV's, compared to ICE vehicles, is fueling. Whereas ICE's are fueled by driving to a separate location, staying there for a few minutes and leaving, charging an EV takes more time, but can be done anywhere. Charging an EV from zero to full can take anywhere between 30 minutes and 2 days, depending on battery size and charging power. Also, cars are being used with a 5 % efficiency (Bates and Leibling, 2012), which means that 95 % of the time they can be charged anywhere they are parked. This creates a demand for EV charging infrastructure everywhere EV's can be parked.

EV charging locations can be divided into three groups: private, semi-public and public (Kley et al., 2011). Private charging means charging in completely private locations, e.g. your own garage. Semi-public charging means charging in a private location, e.g. a housing company or an office building, and restricting usage to e.g. inhabitants or employees. Public charging means charging in locations where usage is available for everyone without any discriminatory restrictions.

In Finland, the availability information of public charging stations has to be accessible by the end user (Finlex, 2017). This creates a need for digital services to mediate the information. Public EV charging networks have grown out of this need to connect EV drivers to charging stations.

Based on this definition there are two public charging networks in Finland. Both create customer contracts with both sides of the network. For charging point owners, they offer access to the network. For EV drivers, they offer customer accounts with possibility for payments (Virta, 2017; Fortum, 2017). EV drivers have to also be able to use the network without a customer contract (Finlex, 2017).

The automotive industry is globally the largest; the top ten car manufacturers have a combined yearly turnover of 1.32 trillion dollars (Statista, 2017). The demand for public EV charging services grows on-par with the amount of EV's (IEA, 2017). As EV's take a larger portion of this trillion-dollar market (Figure 2), it is clear that public EV charging is becoming a significant global network market. Succeeding in the tightening competition requires deeper understanding of the players involved, their interdependencies, and especially the factors contributing value for them.

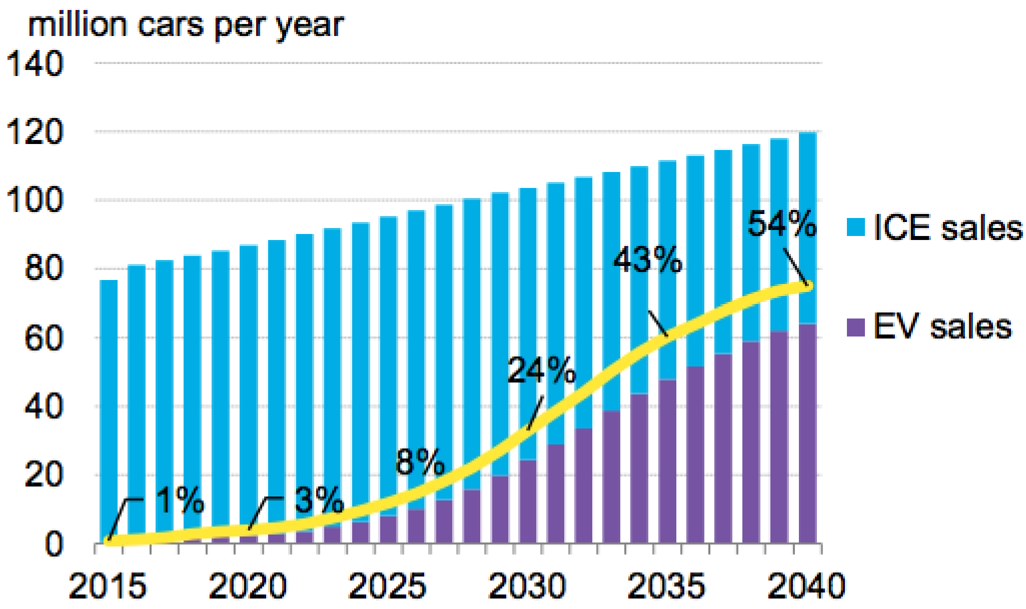

Figure 2. EV vs. ICE sales forecast and EV market share 2015-2040 (Bloomberg New Energy Finance, 2017)

1.2 Approach

The goal of this thesis is to find out how an EV charging network can succeed. To achieve this goal this thesis will answer the following research question:

What factors contribute to the value of an EV charging network for its participants?

Firstly, to answer the question existing literature is explored from two distinct areas: platform economics and EV charging research. As there are noticeable research gaps in the context of the thesis, the first two research objectives are to understand an EV charging network and to identify key factors affecting the value of the platform for participants. Both are achieved through a critical investigation of earlier research.

Secondly, to understand which factors are relevant there is a need to examine a real-life EV charging network. Thus, the third and fourth research objectives are to explain the EV charging network; its structure, participants and their interdependencies and to identify factors that are significant in adding or reducing value for EV charging network participants in real-life situations. The goal is reached by applying the theories suggested by earlier research in a single case study.

In total, when all of the objectives are reached, they help in answering the research question of this thesis. In addition, this knowledge helps to start a new discussion about EV charging networks as platforms and serves as a valuable starting point for future studies.

This thesis focuses only on public EV charging, as semi-public and private EV charging stations are typically limited to individual users. Even though some EV charging operators offer all three types, the fundamental difference creates a new dimension to the platform logic and thus is left out of the scope of the thesis.

1.3 Structure

The thesis follows a linear analytic structure, which is a typical approach for composing an explanatory case study (Yin, 2009). The report includes six chapters: Introduction, Literature review, Methodology, Findings, Analysis and Conclusions.

In Chapter 2, Literature review, earlier research from two perspectives are critically examined and summarized. Firstly, studies related to the platform concept are reviewed from information system science research. The goal is to build a holistic picture on multi-sided platforms, their characteristics and key decisions operators need to address. Secondly, existing EV charging literature from various fields is analyzed. The goal is to understand the underlying technologies affecting the emerging industry and to identify industry players, their roles and interdependencies. Thirdly, knowledge from the two areas is synthesized to build a basis for the case study.

In Chapter 3, Methodology, the specific ways, i.e. methods, used to answer the research question of this thesis are explicated. First, the chapter starts with an analysis of the research philosophy of the researcher, followed with an overview of the case study. Next, the actual methods i.e. methods for data collection and methods of data analysis, are introduced. Finally, the research approach is strengthened with an introduction to research validation methods.

In Chapter 4, Findings, the empirical data of the case is introduced. The findings are showcased from the EV charging network's, from the EV drivers', and from the charging point owners' perspectives.

In Chapter 5, Analysis, the theoretical framework and the empirical findings are used to analyze the case. First, the case EV charging network is analyzed as a multi-sided platform. Next, the factors affecting the value of the platform for participants are analyzed and explicated. Finally, the theoretical framework is revised based on the results.

In Chapter 6, Conclusions, the main findings of this thesis are summarized. In addition, the theoretical contributions and managerial implications of the case study are analyzed. Finally, the limitations of the thesis and suggestions further research topics in the field of EV charging are introduced.

2 Literature review

Developing relevant theories before collecting any data is crucial when conducting case studies (Yin, 2009). This chapter starts with an evaluation of earlier research linked to the research theme from two perspectives. First, the platform concept is introduced to form a basis for a framework. Next, existing research linked to EV charging is introduced to build an understanding of the context of the research topic. Finally, based on the two previous parts a framework is synthesized to support the case analysis.

2.1 Platforms

Even though similar concepts, sometimes with a different name, have existed previously both in academia and industry, the development of the term platform has been fueled by the rise of digital technologies and there is a lack of a widely accepted clear definition. It should be noted that initially the term is used in a more generic manner, defining it as the chapter goes deeper into the context of the thesis.

2.1.1 Development of the platform concept

Initially the term platform became popular in research studying product development processes of individual firms. This product platform concept was used within research areas like mass customization, product modularity and product architecture, i.e. referencing sets of related but differentiated products (e.g. Alsawalqah, Kang & Lee, 2014; Krishnan & Gupta, 2001; Shibata & Kodama, 2015).

In a second phase, the concept industry level platform was developed alongside the initial ideas. The concept describes the product platform as expanded entities serving the cooperation of several companies inside a supply chain (e.g. Brusoni & Prencipe, 2009; Huang, Zhang & Liang, 2005; Zirpoli & Caputo, 2002) and also in bigger and looser ecosystems (e.g. Boudreau, 2010; Boudreau & Lakhani, 2009; Ceccagnoli, Forman, Huang, & Wu, 2012; Gawer, 2009).

According to Gawer & Cusumano (2002) industry platforms are different than single-firm in-house platforms, i.e. product platforms, in two distinct ways. Firstly, the value of the industry level platform is created with complementary innovations by other companies. The platform has to have open and accessible interfaces for this situation to occur. In practice, the platform technology should be easily adoptable by outside innovators. Secondly, the positive feedback loops, so called network effects, can grow the value of the platform exponentially. Complementarities and network effects have been at the core of platform research, as they explain many key characteristics of platforms and platform markets (e.g. Chou & Shy, 1990; Katz & Shapiro, 1985; Katz & Shapiro, 1994; Rohlfs, 1974). Due to their importance, network effects will be discussed more thoroughly in a separate section later in this chapter.

In the third phase, we have seen the rise of multi-sided platform research. Whereas in industry level platforms participants might only transact with the platform provider, in multi-sided platforms the platform mediates transactions between participants (e.g. Armstrong, 2006; Gawer, 2014; Eisenmann, Parker & Van Alstyne, 2006; Rochet & Tirole, 2003). Due to their importance, multi-sided platforms will be discussed more thoroughly in a separate section later in this chapter.

Gawer (2009) describes the evolution of platform research showcased in this chapter in her typology of platforms (Table 1). It emphasizes that all platform concepts have evolved from the need for increased efficiency. A key trend is also moving from simple, one-firm systems to large ecosystems where interaction is complicated and unpredictable.

Gawer (2009) states that the development of platforms is intertwined with the development of business in general. Initially with the birth of the industrial firm there was a clear division based on expertise: engineers focusing on products and business managers focusing on markets. The rise of modern platform businesses has removed this division and blurred the line between the two sides.

In research, the different aspects have affected the development of the platform concept, which has led to varied and growingly inconsistent use of the terminology and definitions. Like the development of the concept has showed, it is not clear how the term platform should be used (Hagiu & Wright, 2015). This is why two perspectives will be introduced to bring clarity for this thesis. The perspectives describe the same phenomenon introduced previously in this chapter, but make clear divisions between product and market.

Table 1: Typology of platforms (Gawer, 2009)

Type of platform	**Internal platforms**	**Supply chain platforms**	**Industry platforms**	**Multi-sided markets or platforms**
Context	Within the firm	Within a supply chain	Industry ecosystems	Industries
Number of participants	One firm	Several firms within a supply chain	Several firms who don't necessarily buy or sell from each other, but whose offering must function together as a part of a technological system	Several firms (or groups of firms) who transact with each other through the intermediary of a double- or multi-sided market
Platform objectives	To increase the productive efficiency of the firm To produce variety at lower costs To achieve mass customization To enhance flexibility in the design of new products	To increase productive efficiency along the supply chain To produce variety at lower costs To achieve mass customization To enhance flexibility in the design of new products	For the platform owner: To stimulate and capture value from external complementary innovation For complementors: To benefit from the installed base of the platform, and from direct and indirect network effects of complementary innovation	To facilitate the transactions between different sides of the platform or market
Design rules	Re-use of modular components Stability of system architecture	Reuse of modular components Stability of system architecture	Interfaces around the platform allow plugging-in of, and innovation on, complements	Not usually addressed in the economics literature
End-use of the final offering	Known in advance and defined by the firm	Known in advance and defined by the assembler/integrator of the supply chain	May not be known in advance, variety of end-uses	Not usually a variable of interest in the economics literature
Key questions in the literature	How to reconcile low cost and variety within a firm?	How to reconcile low cost and variety within a supply chain?	How can a platform owner stimulate complementary innovation while taking advantage of it? How can incentives to create complementary innovation be embedded in the design of the platform?	How to price the access to the double- or multi-sided market to the distinct groups of users, to ensure their adoption of the market as an intermediary?

Product development, technology strategy and industrial economics

The first perspective describes three overlapping theoretical paths that depict the development and history of platform related research. The three paths, first introduced by Baldwin & Woodard (2009) and later expanded by Constantiou, Eaton & Tuunainen (2016), are product development, technology strategy and industrial economics.

The product development path, similar to the product platform concept, refers to structuring a single firm's assets so that generations or families of products can be built efficiently based on a shared product platform (Figure 3). The concept is typical in e.g. the automotive industry. These single-firm in-house platforms are also referred to as interior platforms, and they were initially the only meaning for the platform term in research (Porch et al., 2015).

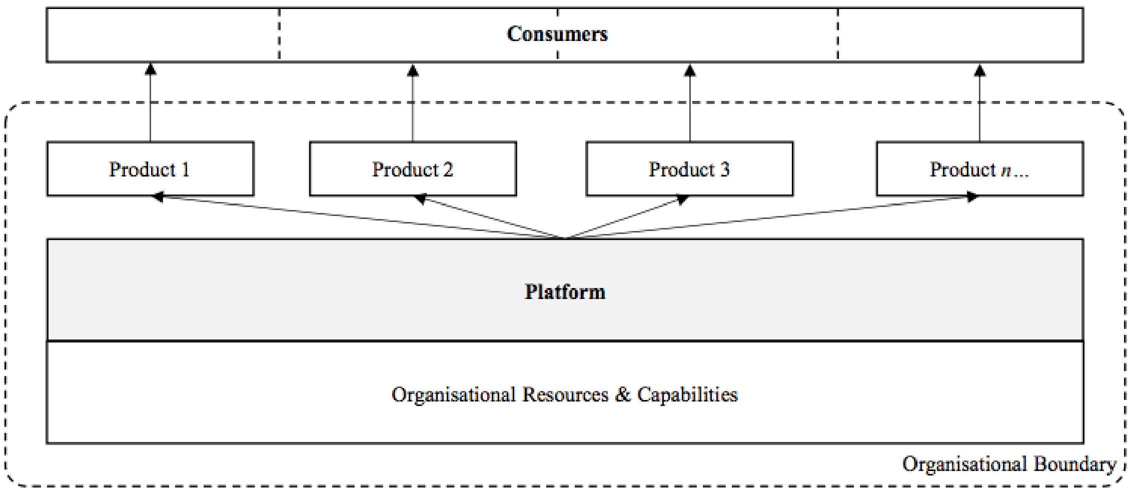

Figure 3.Interior platform structure (Porsch et al., 2015)

The technology strategy path, similar to the industrial level platform concept, refers to a platform being a foundation for an innovation ecosystem, which serves especially industrial level collaboration, where other firms built their technologies on top of a platform technology (Figure 4). The concept can be used to describe e.g. desktop operating systems.

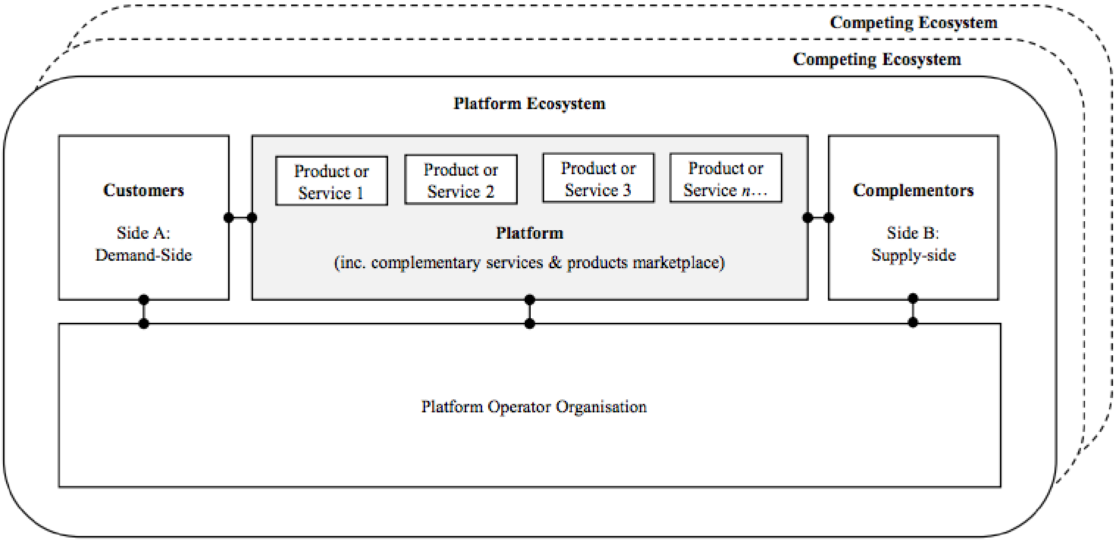

Figure 4. Exterior platform structure (Porsch et al., 2015)

The industrial economics path, similar to the multi-sided platform concept, refers to organizations, services and products that mediate transactions between different players. This path includes concepts like subsidiaries, network externalities and pricing. The concept can be used to describe e.g. digital collaborative consumption services.

Even though the platforms described by these paths vary significantly, Baldwin & Woodard (2009) argue that they share a common backbone in engineering design. They argue that structurally all of the platforms are modular systems built from a reusable platform, its complements, interfaces that mediate interaction, and access rights.

Economics view and engineering design view

The second perspective, introduced by Gawer (2014), includes two evolutionary paths in platform research, i.e. the economics view and the engineering design view (Table 2). Compared to the product development, technology strategy and industrial economics paths, Gawer's perspective is less generalizing and less categorical.

Table 2: Platforms in economics and engineering design (Gawer, 2014)

Literature	Economics	Engineering design
Conceptualization	Platforms as markets	Platforms as technological architectures
Perspective	Demand	Supply
Focus	Competition	Innovation
Value created through	Economies of scope in demand	Economies of scope in supply and innovation
Role	Coordinating device among buyers	Coordinating device among innovators
Empirical settings	ICT	Manufacturing and ICT

Like with previous similar concepts, the economics view sees platforms as efficient marketplaces. The role of the platform is to coordinate transactions between buyers and sellers, typically supported by ICT. In contrast, the engineering design view sees platforms as innovation hubs, facilitating innovating among participants to create new offerings to the market. In addition to ICT the same logic applies also to platforms built around physical products.

As an important argument Gawer (2014) points out that both sides include components that are rarely separate in the real world, complementing his earlier idea of modern platform businesses blurring the line between engineering and business (Gawer, 2009). Based on this argument he proposes an integrative framework bridging the two sides together, a similar idea suggested also by Boudreau (2010) and Eisenmann, Parker & Van Alstyne (2006).

Forming such an integration is however out of the scope of this thesis. This is why, for clarity and focus, this thesis follows the economics side of the definitions, i.e. the economics view (Gawer, 2014) and the industrial economics path (Baldwin & Woodard, 2009; and Constantiou, Eaton & Tuunainen, 2016). These ideas are reflections of the multi-sided platforms concept (e.g. Armstrong, 2006; Gawer, 2014; Eisenmann, Parker & Van Alstyne, 2006; Rochet and Tirole, 2003), which, together with the previous definitions, are used to form a basis for the theoretical framework.

2.1.2 Multi-sided platforms as mediators

According to Gawer (2014) a multi-sided platform is a concept referring to a market that facilitates interaction between two or more customer groups who benefit from comparably lower transaction costs. A similar definition has been used by other notable studies, e.g. Armstrong (2006), Eisenmann, Parker & Van Alstyne (2006), and Rochet & Tirole (2003).

Evans & Schmalensee (2007) saw multi-sided platforms as dynamic catalysts, not just passive facilitators. Even though their concept has not been widely recognized, they were successful in summarizing three activities that lead to the lower transaction costs. Firstly, customer groups are formed when customers are drawn to the platform due to the value proposition of mediating transactions. Secondly, platforms offer search and other information methods to stimulate transactions among the customers. Thirdly, the transactions are governed and coordinated by clear rules. These three activities lead to an efficient and effective market mediated by the platform.

Hagiu & Wright (2011) have been most successful in developing a comprehensive and clear definition for the multi-sided platform concept:

"*Multi-sided platform (MSP): an organization that creates value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers.*"

The definition breaks down into six distinct parts (Table 3). Firstly, Hagiu & Wright define organization loosely, including e.g. firms, groups of firms, not-for-profit organizations, municipalities and even parts of organizations. Secondly, the primary activity of this organization should be enabling direct interactions between its clients.

Thirdly, the organization should allow the direct interactions, whether they are communication, exchange or consumption, to be fully controlled by the customer. Fourthly, at least one interaction (communication, consumption or exchange) should take place on or through the platform, so that the organization is actually the enabler.

Fifthly, all customers should be consciously affiliated with the organization, typically also meaning a fixed investment when joining. Sixthly, the customer type should be distinct at the point of interaction, not when they affiliate with the organization. This creates a more flexible approach compared to older network effect and pricing structure based definitions.

Table 3: Six parts of the multi-sided platform definition (Hagiu & Wright, 2011)

Part	**Definition**
Organization	Understood loosely
Source of value	Enabling interactions has to be the primary source of value
Direct interactions	Participants should have full control over direct interactions
Enabler	At least one interaction (communication, consumption or exchange) has to happen on or through the platform
Affiliation	Conscious, typically involving a fixed investment
Customer types	Distinct at the point of interaction

Hagiu & Wright's definition works only if all variables are taken into account, as ignoring even one of them might mean that the organization's business model is closer to a vertically integrated firm or a reseller than a multi-sided platform (Figure 5), e.g. if the interactions between customers are not direct.

For example, when watching a traditional TV customers are not in full control of the interaction. The channel connects the customer to production companies, but in practice controls the content, making it a reseller by definition. Also, a typical reseller-supplier connection typically lacks the conscious affiliation.

A key characteristic of the definition is that the variables are not binary, but more like a spectrum, and they might change in time. This makes the definition adaptable and flexible. Due to this adaptability, and the overall clear and comprehensive structure, it is a suitable definition when researching a continuously developing and disorganized industry.

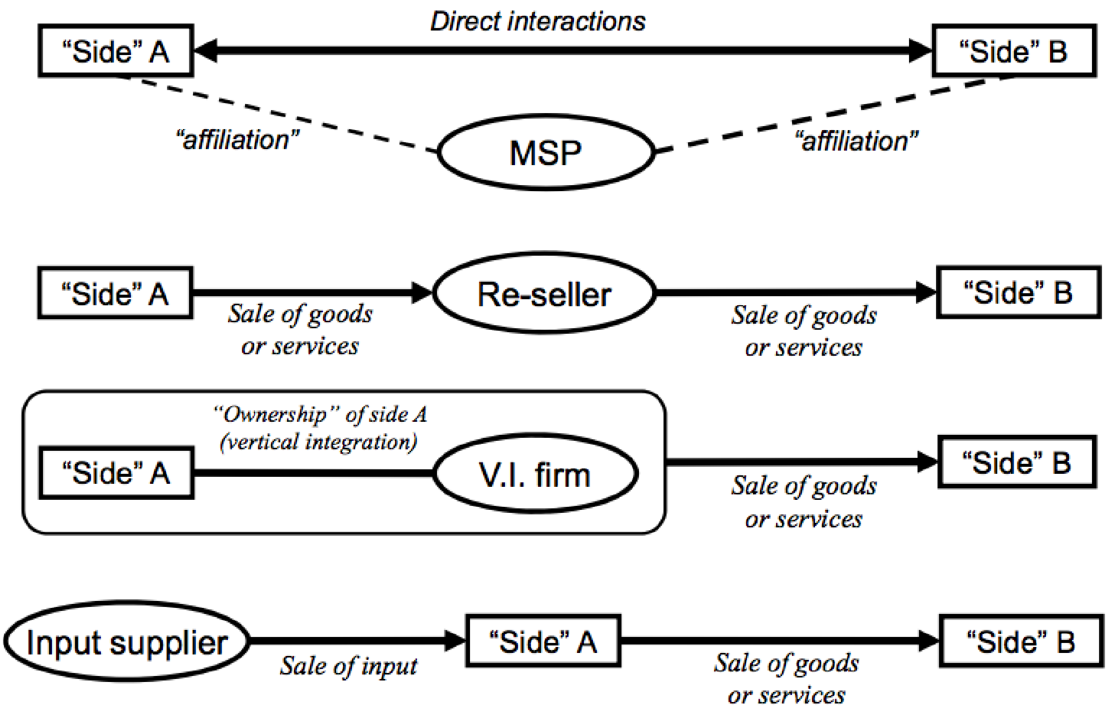

Figure 5: MSP compared to alternative business models (Hagiu & Wright, 2015)

2.1.3 Multi-sided platform characteristics

As mentioned in the previous chapter, multi-sided platforms create value by lowering transaction costs between two or more customer groups. In addition, free-riding becomes a lesser problem on a multi-sided platform due to governance rules (Evans, 2003). Both of these phenomena are examples of network externalities.

Network externalities refer to the total impact of the activities taking place on a network, but which are not consciously noticed and internalized as a part of the value of the network (Katz & Shapiro, 1985; Liebowitz & Margolis, 1998).

The externalities can result from a passive network affiliation or from an active network interaction, e.g. consumption, communication or exchange, in networks where affiliation is not restricted (Rochet & Tirole, 2006). A classic example of the phenomenon is a user not understanding the value of the millions of potential connections when buying a telephone.

Network externalities are often used synonymously with network effects (e.g. Shapiro & Varian, 1999), but they should be distinguished. Liebowitz & Margolis (1994) and Katz & Shapiro (1994) separate the concepts by stating that network externalities are market failures, and they become network effects only when they are being acknowledged consciously.

A network effect is the impact of the change in the number of members on the value of the network for a member. This means that gaining or losing members on one side effects the value of the platform for members on the same or other sides (e.g. Armstrong, 2006; Chou & Shy, 1990; Katz & Shapiro, 1994; Parker & Van Alstyne, 2005). For example, it is easy to hypothesize that more drivers on the ride-sharing platform Uber lowers its value to other drivers due to increased competition, but increases its value to consumers due to increased availability (Figure 6). These are examples of same-side and cross-side network effects respectively and they can be either positive or negative (Table 4).

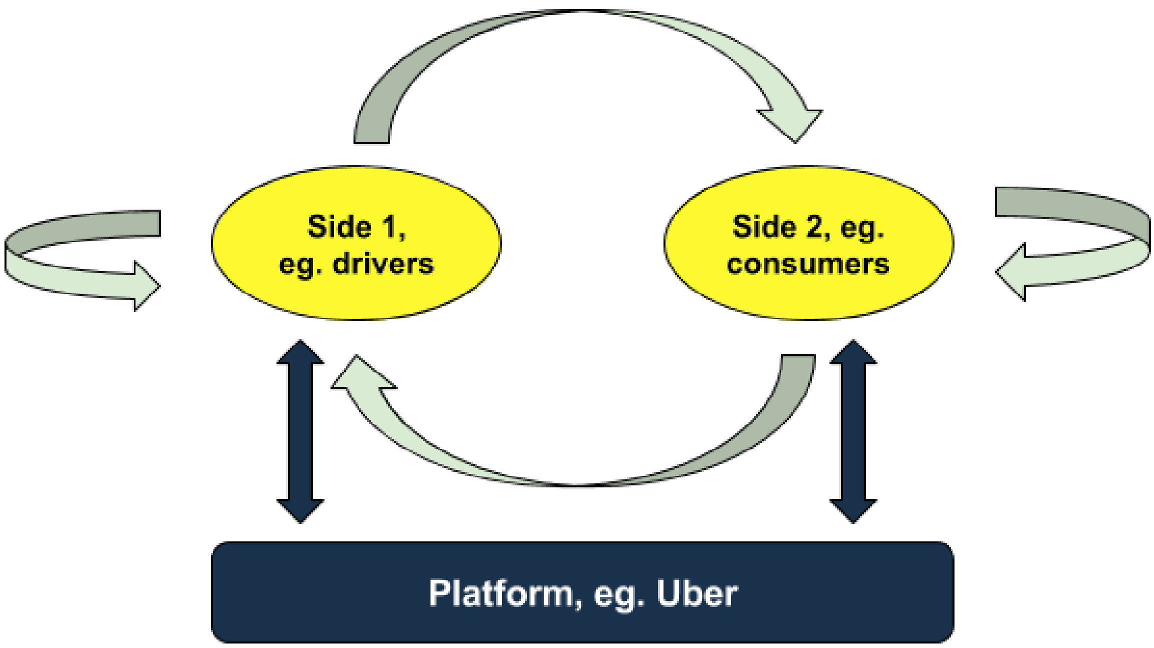

Figure 6. Network effects on a multi-sided platform

Table 4: Types of platform network effects

		Side	
Orientation		*Same-side*	*Cross-side*
	Positive	Same-side positive effect	Cross-side positive effect
	Negative	Same-side negative effect	Cross-side negative effect

In a multi-sided network, network effects reveal interdependencies between platform participants and create a feedback loop when new members affiliate (Gawer, 2014). This means that there is a chain of events, short or long, depending on the size and direction of the network effects. For example, if a platform with positive cross-side network effects can attract more members on one side, more members will follow on the opposite side, after which more members follow on the first side and so on.

This feedback loop has been previously described as demand side economies of scale (e.g. Katz & Shapiro, 1985; Parker & Van Alstyne, 2005; Shapiro & Varian, 1999). At best this phenomenon creates accelerated growth and strengthens the role of the platform in the market by raising the barrier to entry.

However, the same effect causes a major challenge for platforms: how to find the first participants, if one side is following the other. The phenomenon is called the chicken-and-egg problem (e.g. Caillaud & Jullien, 2003; Gawer & Cusumano, 2002). In practice, a low number of participants makes a platform unattractive for potential network members. The challenge of getting several sides to join a platform is the most important competitive factor between multi-sided platforms (Gawer, 2014).

To succeed a multi-sided platform has to ensure gaining a large enough number of members on all sides at the same time for the market to sustain (Evans, 2009). An imbalance between platform adaptation on different sides will lead to failure. Evans (2009) has visualized the optimal growth path towards a balanced and sustaining market with the triangle OC'-C'' (Figure 7). The challenge can be tackled for example by offering a service for a lowered price, for free or even by paying the first side to join.

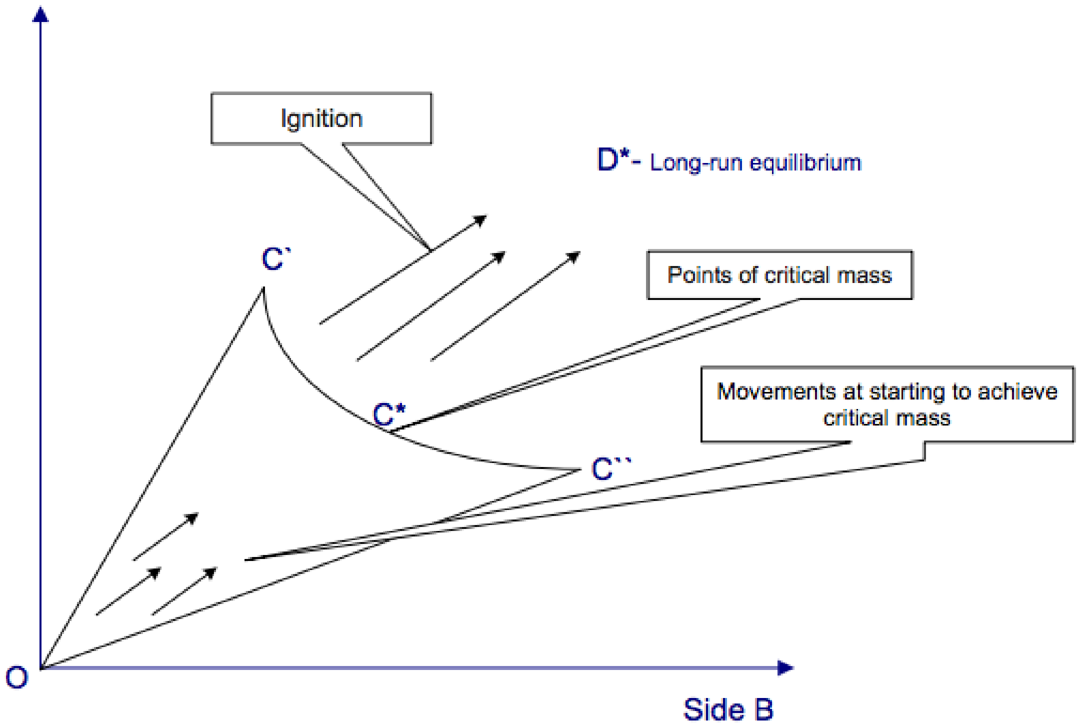

Figure 7. Optimal growth path of a multi-sided platform (Evans, 2009)

This competition is affected by homing, i.e. how many different platforms most of the participants use at the same time (e.g. Armstrong, 2006). Homing is side-specific and typically divided into mono- or multi-homing, depending on if most users use just one or several platforms at the same time. Efficiency is the most important factor affecting homing (Evans, 2003).

Shapiro & Varian (1999) argued that the positive feedback loops caused by network effects cause self-fulfilling consumer expectations, which eventually lead in the dominance of a single platform. But later Evans (2003) argued that because of multi-homing several platforms can survive and even thrive side-by-side. In any case, homing is an important phenomenon that can't be ignored, as in extreme cases it can be a key component in a winner-take-all situation, where one platform enjoys a de facto monopoly position (Armstrong, 2006).

2.1.4 Multi-sided platform decisions

Pricing strategies are a key area in motivating customers to affiliate with and stay engaged on a platform (Evans, 2003). In addition, pricing can be used to control access to the platform by making affiliation unfavorable to unwanted prospects as the quality of participants defines the strengths of indirect network effects (Hagiu, 2014).

Unlike with pricing strategies with traditional products and services, the pricing for an MSP cannot be calculated based on demand or marginal costs. Instead, pricing should be side-specific and based on network externalities, making generic best practices obsolete (Eisenmann et al., 2006; Rochet & Tirole, 2004). This has led to most MSP's having a strongly skewed pricing scheme with subsidy sides, getting less value and paying less money, and money sides, getting more value and paying more (Eisenmann et al., 2006).

The skewed and subsidized pricing schemes are used to first attract one side to tackle the chicken and egg problem and create growth with positive feedback loops that are caused by positive cross-side network effects (Evans, 2003; Eisenmann, 2008; Gawer & Cusumano, 2008). Even though a subsidizing pricing scheme can create growth with cross-side network effects, same-side network effects may cause challenges and should be taken into account when deciding which side to subsidize (Eisenmann et al., 2006).

An optimal pricing strategy should be based on price sensitivity and value gained from using the platform. As a rule of thumb the side that is more price sensitive should be subsidized and the side that gains more value from using the platform should pay more (Armstrong, 2006; Eisenmann, 2008; Hagiu, 2014).

Pricing is a widely used tool for controlling the quality of participants and avoiding negative effects (Hagiu 2014, Boudreau & Hagiu 2008, Rochet & Tirole 2004, Parker et al., 2016), but there are also non-pricing governance mechanisms. Non-pricing governance mechanisms are controlling access to the platforms, i.e. getting the right participants, and controlling interactions on the platform, i.e. getting participants acting in the right way (Boudreau & Hagiu, 2008, Hagiu, 2014, Van Alstyne et al., 2016).

These non-pricing governance mechanisms are also known as boundary resources (Ghazawneh & Henfridsson, 2013), i.e. interfaces between a platform provider and its participants. In practice they can be administrative, cooperative, functional, informational, legal, technological, and other instruments (Boudreau & Hagiu, 2008; Ghazawneh & Henfridsson, 2013). E.g. established technical standards and application public interfaces

(API) are typical technological instruments, and terms of service is a typical legal instrument.

Boundary resources are an effective tool in minimizing negative network effects by selecting platform participants and controlling their interactions (Ghazawneh & Henfridsson, 2013). This is because they minimize costs linked with many network externalities, e.g. asymmetric information, coordination problems, complexity and uncertainty (Boudreau & Hagiu, 2008). In practice, this means solving market failures, i.e. situations where unfair interactions occur or where mutually satisfactory interactions fail to occur (Parker et al., 2016).

Lastly architecture is fundamental platform decision, as for example openness of the platform determines the growth potential (e.g. Boudreau & Hagiu, 2008; Cusumano & Gawer, 2002; Eisenmann, 2008; Evans & Gawer, 2016; Parker et al., 2016).

A platform can be open or closed, not in a binary way, but rather like a continuous spectrum. On the other end a closed platform is limited only to the members of the platform organization, like the in-house product platforms described earlier in this chapter. An open platform extends beyond the organization and includes third parties. On the most open-end of the spectrum are digital multi-sided platforms with little governance.

Open platforms allow freedom for external third parties and free platform providers from some tasks, making them ideal for decentralized innovation (Olleros, 2008). Platforms promoting third-party innovation grow faster compared to those who do not, as they accelerate growth by decreasing lock-in concerns and capturing network effects (Parker & Van Alstyne, 2008). On the other hand, open platforms can have a negative impact on profit due to technical investments to interoperability and to sharing revenues with platform members (West, 2003).

Modularity is a widely used approach for an open platform structure. A modular platform comprises of independent units that work together as an integrated whole (Parker et al., 2016). A platform built from modules makes complexity easier to manage and increases innovation, as new connections can be easily built (Gawer, 2014; Tiwana et al., 2010; Tiwana, 2014).

Parker et al. (2016) argue that to succeed in the long-term platforms should create an open modular architecture, as the design allows for independent subsystems to form, creating new value to the platform through these new integrated features and approaches. These subsystems and other innovations can be added to the value proposition of the platform (Ethiraj et al., 2008; Staykova & Damsgaard, 2015), and as they are created by members specializing in the specific topic, modularity also increases operational efficiency (Thomas et al., 2014; Tiwana et al., 2010).

Even though complementary innovations and new features can initially create more value for participants, too many new interactions can lead to too much complexity, which can be harmful (Parker et al., 2016; Tiwana, 2014). The platform evolves faster, when user experience is kept as clean as possible. This is why core functionalities should be developed slowly, and fast adaptations should be allowed in areas that affect only particular users (Parker et al., 2016).

2.2 Electric vehicle charging

Even though EV's dominated the market in the early 1900's and had a brief comeback in the 1990's, their history really starts in 2006 when they started to increasingly appear on the agenda (Sierzchula et al., 2012). Like with most ICT enabled businesses, the business logic of EV charging is heavily dependent on technological boundaries. In addition, recognizing key agents in the industry is needed to understand the context of the real-life case.

2.2.1 Technology for EV charging

In the beginning of the decade the European Parliament drafted a resolution to promote and support EV's in personal transportation (EU, 2010). This resolution aims to create a single European market based on shared technical standards. The standardization of the charging infrastructure and technologies with open communication protocols serves as a foundation for the development of the industry.

On a very basic level an EV can be charged using a charging point or a socket-outlet. A charging point is the connection between an EV and the charging infrastructure that provides electricity to the vehicle. A charging station is a collection of one or multiple charging points. The charging station and its connection to the electricity distribution grid as a whole can be referred to as electric vehicle supply equipment (EVSE). (San Roman et al., 2011)

From a physics perspective charging can be divided into two basic types: alternative current (AC) and direct current (DC) charging. AC EVSE feeds AC electricity to the car, where an on-board charger transforms it to DC electricity for the car battery. DC EVSE includes an off-board charger, which feeds DC electricity straight to the battery. Typically, AC charging is the normal option, whereas the costlier DC charging stations are used for fast charging that support intercity travel. (Rautiainen, 2015)

Kley et al. (2011) identify three elements in a charging system: an EV, EVSE and an operator system. In addition, there are three connections among them: a connection between an EV and EVSE, which can be uni- or bidirectional; a connection between the EVSE and the operator system, which aggregates multiple EVSE's; and a connection between the EVSE and the electrical grid.

The widely respected international standard IEC 611851-1 categorizes four charging modes which describe the communication protocol used between the vehicle and the charging device (Table 5). They are the de facto standards in the industry and help players understand technical applications more easily (Rautiainen, 2015).

Mode 1 is an AC charging method mostly for charging of light vehicles, like mopeds, with a low current. The mode is not relevant in the EV context, where passenger cars are the main focus. Mode 2 is an AC method to be used as a temporary or transitional solution, before more sophisticated methods become more common. (Rautiainen, 2015)

Mode 3 is the recommended AC method for day-to-day charging, and includes important smart features, like an ICT connection between the EV and the EVSE, so that a charging power can be controlled during a charging event (Rautiainen, 2015). A Mode 3 standard called Type 2 is the de facto connector in Europe, most notably determined by an EU directive (EU, 2014).

Mode 4 is a DC charging method, in which an off-board charger enables very fast charging speeds (Rautiainen, 2015). There are rivaling connector standards in Mode 4 in Europe, most notably the Japanese CHAdeMO and the European Combo 2 or CCS, which was chosen as the standard to be used in public charging stations in the EU (EU, 2014).

Table 5: IEC 61851-1 standard EV charging modes (Rautiainen, 2015)

Charging mode	**Current**	**Features**
Mode 1	AC	Low current connection Intended for low current charging of light vehicles Not relevant for EV's
Mode 2	AC	Normal current connection Intended for slow charging Transitional solution
Mode 3	AC	Normal current connection Intended for basic charging ICT connection between EV and EVSE Possibility to up- and down-regulate maximum current during charging event
Mode 4	DC	High current connection Intended for fast charging ICT connection between EV and EVSE

In addition to the IEC 611851-1 standard, there is another categorization seen in academic literature and industry with three levels that describe the power output of an EVSE outlet (e.g. Rahman et al, 2016). Level-1 opportunity charging refers to slow charging speeds, and is comparable to Mode 1. Level-2 primary charging refers to normal charging speeds used in the day-to-day, and is comparable to Mode 2 and Mode 3. Level-3 fast charging refers to high speed charging, and is comparable to Mode 4.

The technically oriented EV charging studies have mostly concentrated on technologies that derive from the ability to control uni- and bidirectional charging using Mode 3 methods.

Firstly, the optimal coordination of charging events to protect electrical grids in real-time has been a key focus area, since the mass adoption of EV's poses a major threat to the electrical grid due to increased demand and intense consumption peaks (e.g. Deilami et al., 2011; Gan, Topcu & Low, 2013; Green, Wang & Alam, 2011; Hota, Juvvanapudi & Bajpai, 2014; Mets et al., 2010).

Secondly, studies have examined the positive potential of EV's as a stabilizing element in the grid to support intermittent renewable electricity production (e.g. Andersen, Mathews & Rask, 2009; Caramanis & Foster, 2009). In practice, EV charging should be coordinated based on signals from renewable energy production.

Thirdly, EV's can be seen as distributed energy storages by controlling bi-directional charging (e.g. Guille & Gross, 2009; Mwasilu et al., 2009; Lund & Kempton, 2008). These vehicle-to-grid (V2G) concepts allow EV's to charge when electricity demand is low or supply is high, and discharge when demand is high or supply is low.

2.2.2 Economics of EV charging

EV charging is much more than just moving electricity from the grid to the vehicle. Someone has to build the charging stations and related systems, which cause capital and operating expenses to someone, and this entity needs to be incentivized to do so (Brown et al., 2010).

In importance and volume, the majority of EV charging research with an economics perspective has focused on the optimal planning of charging networks infrastructure. In practice, this means creating methods that determine where, how many and which type charging points should be located based on variables like demographics and driving routes (e.g. Bae & Kwasinski, 2012; Chen, Kockelman & Khan, 2013; Ge, Feng & Liu, 2011; Jia, Hu & Luo, 2012; Nie & Ghamami, 2013).

Some researchers argue that the emerging industry is searching for viable business models (e.g. Christensen et al., 2012; Kley et al., 2011). Different business models have been tried out at the same time across and within firms (Bohnsack, Pinkse & Kolk, 2014). These arguments are slightly outdated, as for example this thesis analyzes a viable business model, which was non-existent at the time of the earlier research.

Rautiainen (2015) simplifies the industry by categorizing EV charging services into three distinct groups based on the openness of the service. The model is a good starting point, but lacks the big picture due to an emphasis on the physical charging infrastructure.

The first category is private or domestic ownership, meaning that EVSE is located in a private property, e.g. a garage, and the owner of the location pays for the electricity and infrastructure costs. The second category is extended private ownership, meaning that the EVSE is located in a private location like a housing company or an office building, and usage is restricted to the inhabitants or employees of the location. In this model the property owner, e.g. a housing company, pays for the electricity and infrastructure costs, and the end user, e.g. inhabitants, pays some fee for charging or for the possibility to charge.

The third category is public and commercial ownership, meaning that the EVSE is located in a location open to anyone without discriminatory restrictions. The owner pays for the electricity and infrastructure, and the end user pays some fee for charging or for the possibility to charge.

Rautiainen (2015) advices service operators to pay attention to pricing mechanisms when designing their services. He suggests that because in normal situations the cost of energy needed for a single charging event is relatively low, there is no need to monitor energy intake and payments should not be based on energy consumption. This would lead to lower infrastructure costs and thus more charging points.

Kley et al. (2011) lay out a similar overview of EV charging services (Figure 8). They identify the same three charging service types: private, semi-public and public. The service operator should take responsibility for installation, maintenance and billing. The cost of charging can vary: charging can be free, pay per use or with a fixed rate. Unlike Rautiainen (2015), Kley et al. do not discuss the financial consequences of metering needed for pay per use payments.

Kley et al. (2011) point out that ownership and service models for private and semi-public charging are straightforward, but public charging has more variance and complexity. The study points out that there has been discussion around ways to build a business model around public charging and options for market mechanisms, but it stays unclear who they are referring to.

The study by Kley et al. (2011) stumbles on the same narrow view and hardware oriented thinking as Rautiainen (2015) did. This lack of the big picture and thorough technical orientation is best seen in their systematic description of business models for EV charging (Figure 8).

Infrastructure				
Characteristic	**Design possibility**			
Type of power supply	Conductive (wired)	Inductive (wireless)	Battery exchange	
Accessibility	Private	Semi-public (e.g. at employer)	Public	
Power connection	1-phase (Level 1)	3-phase (Level 2)	High voltage AC (Level 3)	High voltage DC (Level 3)
Connection type	Unidirectional	Bidirectional		
Information flow	None	Unidirectional	Bidirectional	
Information processing	Day-ahead	Intra-day	Real-time	
Operator of power supply	Private	State	Energy utility	Independent provider
Type of billing	No fee	Fixed rate	Pay per use	
Metering	No metering	At charging station	In vehicle	

Requirement of technical & organizational change

Fig. 3. Morphological box for the systemic description of business models for constructing and supplying infrastructure.

Figure 8. Systemic description of business models for EV charging infrastructure (Kley et al., 2011)

In contrast, San Roman et al. (2011) have created the most comprehensive overview of the challenges and opportunities in regulatory and business model issues regarding EV charging infrastructure. The study includes suggestions on both market and business model design in the emerging industry. Contrary to other research, San Roman et al. (2011) saw EV charging as an economic rather than a technical pursuit. This is why their work serves as a starting point for the development of a theoretical framework in this thesis.

San Roman et al. (2011) identify two groups of agents in the market: existing and new players. The players and their interactions are displayed in Figure 9.

Existing players include energy market entities: transmission system operator (TSO), who is responsible for national electricity transmission grids; distribution system operator (DSO), who is responsible for local electricity distribution grids; supplier (SA), who sells energy to final customers; and final customer, who purchases electricity.

The first new agent is EV owner, who owns an EV and charges it with electricity bought either from a SA or an EV supplier (definition below). When V2G technologies become relevant an EV owner could also become a supplier of electricity.

The second new agent is EV supplier-aggregator (EVSA), who sells electricity to the EV owner through a variety of charging points. The difference between an EVSA and a SA is that contracts with EVSA are not location based. EV owners need the freedom to move around a geographic area and thus need to be able to access multiple charging points as a customer of the same EVSA. In the future EVSA's can also aggregate EV's and play a key role in selling V2G services to the existing energy market players.

The third new agent is charging point manager (CPM), who installs and manages charging points on its own property. CPM buys electricity from a SA and uses it itself or resells it to EV owners through the charging points under a commercial agreement. Four scenarios for a CPM include a residential customer charging privately at home; an office building offering charging semi-publicly to its employees; a commercial building offering charging semi-publicly to its clients; and an organization offering public charging with several charging points. These scenarios are aligned with Rautainen's (2015) and Kley et al.'s (2011) categorizations of the market.

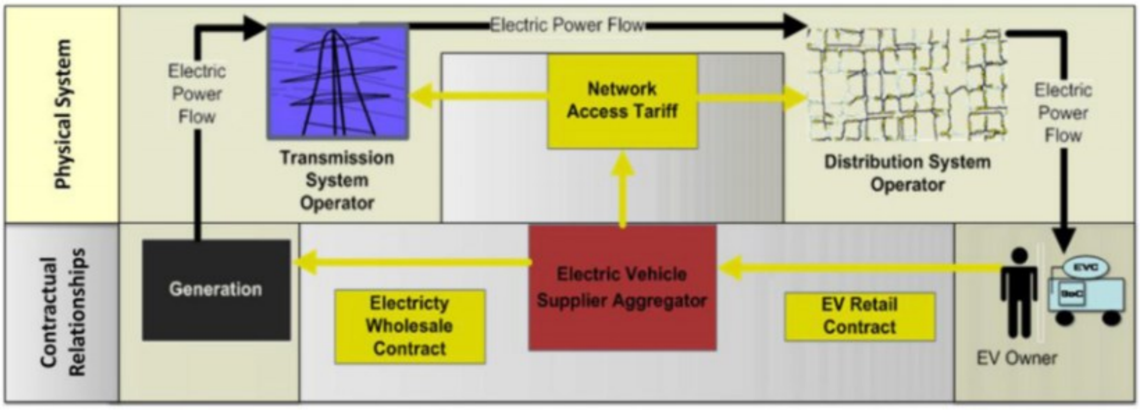

Figure 9. Interactions between agents in an EV charging system (San Roman et al., 2011)

In addition, San Roman et al. (2011) point out two key technical aspects to be considered. Firstly, energy consumption should be metered, and the metering equipment could be connected to an EVSA for billing and remote charging control. This is contrary to Rautiainen's (2015) suggestion. Secondly, a public charging point should include an interface for user identification, physically accessing the connection, measuring energy, billing and removing access after payment.

Based on the agents, San Roman et al. (2011) argue that the business model development in the industry will have three phases. In the first phase, with a relatively low penetration of EV's, charging could be done mostly at homes or other private areas, like office buildings or shopping malls. Charging could be billed by hourly rates that are based on electricity demand.

In the second phase, with high EV sales growth, smart charging (Mode 3) infrastructure should be deployed and there should be an emphasis on public charging points. It is suggested that due to the high costs DSO's would be a natural player to build the network. EVSA's would emerge in this phase and have a high control over the ecosystem.

In the third phase, the long-term stage, EV's would play a key role in the energy system. To protect the energy system from this new electricity demand EVSA's should be responsible for reacting to the needs from TSO's and DSO's and provide ancillary and balancing services. These new needs would create valuable opportunities for the EVSA's.

2.3 Theoretical framework

Aligned with the objectives of this study, there is a need for a theoretical framework for the analysis of empirical data. Firstly, there is a need to understand an EV charging network as a platform; its structure, participants and their interactions. Secondly, there is a need to understand what factors could have an effect on the value of the platform for its participants.

To synthesize this theoretical framework, earlier research is summarized from two perspectives. The first part summarizes the decisions a platform operator makes that may affect platform participants. The second part summarizes the behavior of platform participants that may indicate relevant factors affecting these participants. The third part builds a theoretical framework based on this summary.

2.3.1 EV charging network operator decisions

Architecture affects how participants can access the platforms resources and create new sources of value (Parker et al., 2016). In practice, the openness of this architecture is crucial as it affects participants motivation and determines the growth potential (Evans & Gawer, 2016). Selecting how many sides a platform has can also have a positive or negative effect on the value of the platform (Hagiu, 2014).

San Roman et al. (2011) introduced all relevant agents and interactions between them in the EV charging ecosystem. Derived from this categorization there are four distinctive agents in an EV charging network (Table 6). The EV supplier-aggregator (EVSA) mediates transaction between other agents. The charging point manager (CPM) owns, installs and manages charging devices. The electric vehicle owner (EV) charges its vehicle using the CPM's' charging devices. The energy system (ES), consisting of a supplier, a distribution system operator and a transmission system operator, provides electricity to the CPM, and in the future buys V2G services from the EVSA.

Table 6: EV charging platform agents derived from San Roman et al. (2011)

Agent	**Description**
Electric vehicle supplier-aggregator, EVSA	An organization that mediates transactions between EV's, CPM's and the energy system
Electric vehicle owner, EV	A person or an organization that uses and charges an electric vehicle
Charging point manager, CPM	A person or an organization that owns and manages one or multiple charging points, and offers them for public use
Energy system, ES, incl. SA, DSO and TSO	Organizations in the energy industry that can benefit from EV based ancillary and balancing services

By definition a multi-sided platform (MSP) is an organization creating value by mediating interactions between two or more sides (Hagiu & Wright, 2011). Based on San Roman et al. (2011), the EVSA mediates three different transactions between the three sides (Figure 10). Firstly, information about the charging station, e.g. if it is free or not, is mediated from CPM to EV. Secondly, EV can control the charging station, e.g. a signal is sent from EV to CPM to start charging, and pay to CPM according to the charging event. Fourthly the EVSA aggregates and mediates V2G services and monetary transactions between EV and the energy system.

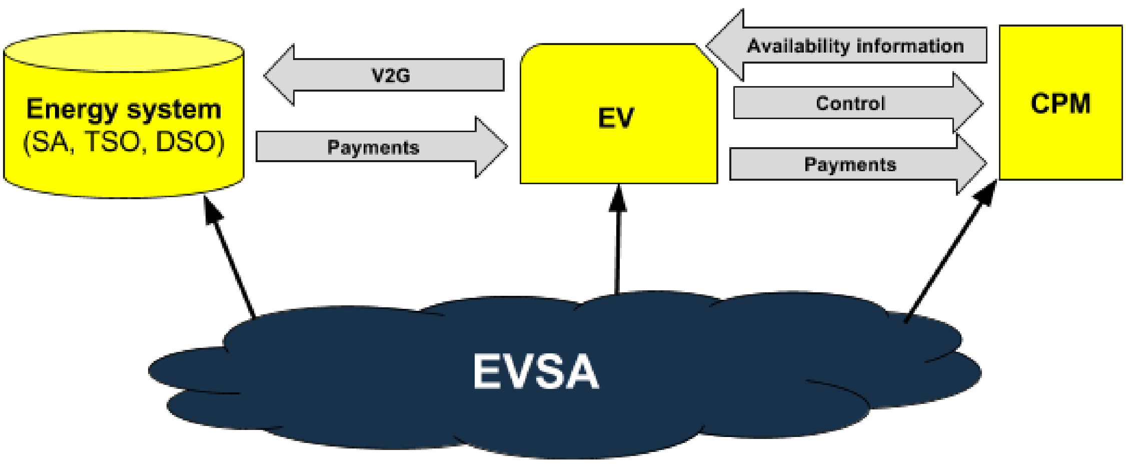

Figure 10. Proposed EV charging network structure and interactions

Due to the outdatedness of the study, San Roman et al. (2011) did not specify the role of a roaming operator. In EV charging, roaming operators connect multiple EVSA's allowing transactions between opposite sides of different platforms, e.g. a CPM on one platform to an EV owner on another platform (EURELECTRIC, 2016). In a sense roaming operators are platforms of platforms. The effect of roaming on EVSA's is left out of the scope of this thesis and calls for more research, as at the time this case study is conducted roaming is not possible in Finland.

Pricing is a key property affecting customers' motivation to affiliate and stay engaged on the platform (Evans, 2003). Pricing should be side-specific and based on network externalities (Eisenmann et al., 2006). Subsidization of one or more sides is used to create positive feedback loops to tackle the chicken and egg problem and spark growth (Parker et al., 2016). As stated, EVSA's currently have three distinct sides, EV's, CPM's, and the energy system, so there are three different effects of pricing to be studied.

Boundary resources are used to get the right participants to join and interact in the right way (Hagiu, 2014). These interfaces between the platform provider and participants can include administrative, cooperative, functional, informational, legal, technological and other instruments (Ghazawneh & Henfridsson, 2013). Boundary resources can be used to increase value by minimizing negative network effects (Ghazawneh & Henfridsson, 2013).

The platform decisions and their key factors are summarized in Table 7. These decisions affect both the affiliation potential participants and the behavior of existing participants.

Table 7: Summary of platform operator decisions

Decision	**Key factors**
Architecture	• Modularity • Openness • Number of sides • Interactions between sides
Pricing	• Subsidization strategies
Boundary resources	• Administrative • Cooperative • Functional • Informational • Legal • Technological • Other instruments

2.3.2 EV charging network participant behavior

Based on earlier research platform participant behavior is reflected in two phenomena: network effects and homing.

A network effect is the impact of the change of members on the value of the network member (e.g. Armstrong, 2006). In addition to direction, the network effects also have a magnitude (e.g. Eisenmann et al., 2006). Based on the definition EVSA's can have nine distinct network effects, three of which are same-side and six are cross-side (Table 8).

Due to network effects a platform has to gain critical mass on all sides for the market to sustain (Evans, 2009). Before this the small number of participants makes the platform unattractive for potential participants. After critical mass is gained the orientation and magnitude of the network effects determine how much they affect the motivation for a participant to affiliate.

Table 8: Summary of proposed network effects in an EV charging network

Trigger, change in the number of	**Effect on the value for**	**Same-side / Cross-side**
EV owner participants	EV owner participants	Same-side
EV owner participants	Charging point manager participants	Cross-side
EV owner participants	Energy system participants	Cross-side
Charging point manager participants	Charging point manager participants	Same-side
Charging point manager participants	EV owner participants	Cross-side
Charging point manager participants	Energy system participants	Cross-side
Energy system participants	Energy system participants	Same-side
Energy system participants	EV owner participants	Cross-side
Energy system participants	Charging point manager participants	Cross-side

Homing means how many distinct platforms different sides most members use at the same time, and it is an important component in MSP competition (e.g. Armstrong, 2006). Currently most IEC 611851-1 standard EV charging devices can connect only to one operator system (e.g. Kley et al., 2011; Rautiainen, 2015). This means that for CPM's multi-homing is possible with two or more charging devices, but most likely not feasible due to lost efficiency.

Similarly, EV's are technically able to create multiple contracts with different EVSA's at the same time, but it might not be economically feasible. Efficiency is the most important factor affecting homing (Evans, 2003), and San Roman et al. (2011) suggest that EV's might benefit economically and have a better user experience when retaining a relationship with only one EVSA.

Energy system participants are prone to multihoming, as gaining a significant impact requires scale (San Roman et al., 2011). Commercial V2G services require a large amount of EV's to be aggregated by an EVSA. The proposed homing behavior is summarized in Table 9.

Table 9: Summary of proposed homing behaviour in an EV charging network

Participant	**Homing behavior**
EV owner	Possibility for multihoming, likely to monohome
Charging point manager	Possibility for multihoming, likely to monohome
Energy system	Possibility for multihoming, likely to multihome

2.3.3 Conclusion of the theoretical framework

Based on earlier research on platforms and EV charging, in an EV charging network there are six dimensions affecting the value of the network for its participants: architecture, pricing, boundary resources, number of EV owner participants, number of charging point manager participants and number of energy system participants. Figure 11 summarizes the interdependencies between these factors.

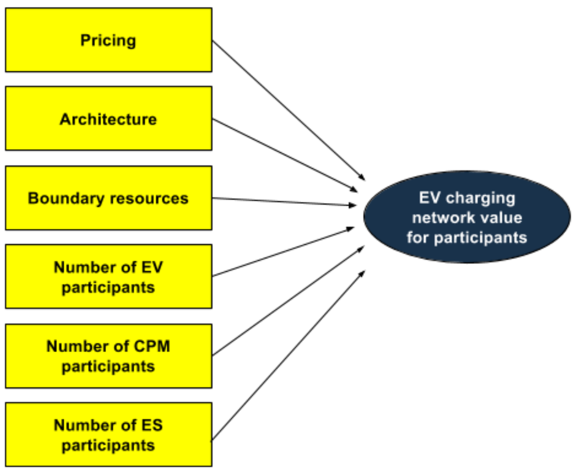

Figure 11. Factors affecting the value of the platform for participants

3 Methodology

This thesis aims to discover how an EV charging network can succeed. To reach this objective this thesis answers the following research question:

What factors contribute to the value of an EV charging network for its participants?

To answer the question an explanatory single case was studied. In the case an EV charging network in Finland was examined. The network operator organization was the unit of analysis, while the two customer groups, EV drivers and charging point owners, were subunits.

This chapter starts with an analysis of the underlying research philosophy. Next, the case study is introduced, starting with case studies as a research strategy, and ending with an introduction to the case. Finally, research validation methods are introduced.

3.1 Research philosophy

Before diving into the actual methodology, there is a need to justify the research approach by explicating the underlying research philosophy as it guides all decisions and is thus extremely relevant. All research methodology, both qualitative and quantitative, is affected by the researcher's philosophy (Eriksson & Kovalainen, 2008). The research philosophy, basically a set of assumptions, is a foundation that determines how meaningful and valid research is conducted.

Yin (2009) states that when conducting case studies researchers should adopt positivism, i.e. a philosophy that sees reality as external from the researcher and their values. Positivism in social sciences, which is based on empiricism, tries to build laws based on causalities. According to the positivist view reality can be simplified into measurable variables. Positivism is the dominant research philosophy in business research (Myers, 2009).

Even though human behavior in social settings can be quantified and that generalizing laws can be valid, it felt uncomfortable to pursue this view in the thesis. Being professionally infused in the industry it seemed inevitable that subjectivity would affect observations and interpretations.

This is why critical realism was adopted as a research philosophy for the research in this thesis. Johnson & Duberley (2000), Reed (2005) and Contu & Willmott (2005) hint that critical realism could be used as a philosophical view when conducting business research. Critical realism is similar to positivism as it accepts that there is an external reality beyond human consciousness (Eriksson & Kovalainen, 2008). However, at the same time, it admits that our world view is somewhat socially constructed.

With a critical realist view, researchers aim to explain reality as accurately as possible, trying to find causalities and laws (Eaton, 2010). While doing so researchers understand that their thinking is constantly affected by their expectations and beliefs (Gray, 2013). They might even think that some of their observations could be illusions. Critical realism allows for subjectivity in research, while believing that reality will break through eventually (Easton, 2010). The reasoning is that in the research area of this thesis there are quantifiable causalities and laws, but that it is out of the scope of this thesis to find them, since as a novel industry there are wide gaps in earlier research.

3.2 Case study research

Case study research is a research strategy used when studying complex issues that are difficult to examine with purely quantitative methodologies (Ghauri & Gronhaug, 2005). Typically case study research definitions emphasize creating holistic and detailed knowledge based on multiple empirical sources rich in context (Tellis, 1997). Case study research leaves room for complexity and diversity avoiding simplified research designs (Eriksson & Kovalainen, 2008).

Case studies examine contemporary phenomenon within real-life context where the line between the phenomena and the context is not clear (Yin, 2009). In case studies researchers ask ‘why’ and ‘how’ to understand and describe the phenomenon. This is why most case studies are exploratory or explanatory (Saunders et al., 2009).

As stated previously, case study research is a research strategy, not a method itself. This means that even though case studies are typically considered a qualitative approach, quantitative data can be also used (Eriksson & Kovalainen, 2008). Almost any empirical data can be used, and also methods of analysing this data can vary significantly.

To conclude, Stoecker (1991) descriptively defines case studies as projects attempting to holistically explain the dynamics of a certain time of a specific social unit. The definition fits well to the goal of the thesis, as it is obvious that the case industry will change drastically in the next decade like described by San Roman et. al (2011). Based on Stoecker's definition this thesis should be perceived as a snapshot of the industry dynamics in its infancy.

This thesis examines an EV charging network in Finland. The service is the national market leader in public EV charging and offers services to two sides. Firstly, the service offers EV drivers[1] access to public charging points by providing an interface to find available charging points, to control the charging point (i.e. start and stop charging), and to pay for charging. Secondly, the service offers charging point owners (CPO)[2] access to the charging network by collecting availability information, by controlling charging events, and by transferring payments. As the service mediates these transactions between the two participants, it can be perceived as an EV charging platform. The arguments for this statement are made later in the Analysis chapter.

Even though Yin (2009) states that multiple case studies should be preferred over single cases, he offers five arguments to support the choice of a single case. The examined case is unique, as it was impossible to examine any other case in the same geographical area. The only competing service has features that do not fit to the definition of a multi-sided platform by Hagiu & Wright (2011). In addition Dyer & Wilkins (1991) argue that there is a wide range of examples of single case studies that have significantly advanced social science theories with a meaningful impact.

With a single case, the thesis was conducted as an intensive, or classic, case study. The goal of an intensive case study is to understand how a case works from the inside and understand the people involved in the case with a thorough contextualized, holistic and thick description (Geertz, 1973). The purpose of thick description is to crystallize the reasons behind the complex details of the case, i.e. to give a verbal interpretation that makes the meanings clear (Shank, 2002).

An intensive case study researcher should focus on constructing a narrative, i.e. a good story worth hearing (Dyer & Wilkings, 1991). This means taking all relevant aspects

[1] Unlike suggested by San Roman et al. (2011), the term EV driver is widely used in the industry instead of EV owner, and thus also when describing the case in this thesis.

[2] Unlike suggested by San Roman et al. (2011), the term charging point owner (CPO) is widely used in the industry instead of charging point manager (CPM), and thus also when describing the case in this thesis.

into account when presenting the case. In this thesis the economic, business, technological and physical context are the dimensions that build the case.

The goal with the intensive case study is not to generalize the phenomenon, but to understand and showcase the unique case. The uniqueness of the case in this thesis appropriates the case study approach (Eriksson & Kovalainen, 2008).

The case is an explanatory case study, as it pursues to answer how an EV charging network succeed and it examines a contemporary phenomenon (Yin, 2009). This systematic development of causal explanations iteratively and flexibly can be called analytic induction. The case was analyzed inductively, which is typicaly for case study methodology (Eisenhardt, 1989).

The case in this thesis can also be described as an embedded case. As stated earlier, the case includes one unit of analysis, i.e. the platform organization, and two subunits of analysis, i.e. the two sides of the platform (Yin, 2009).

3.3 Data collection

Case studies become more convincing, robust, accurate and rich, if they are based on several sources of empirical data (Eriksson & Kovalainen, 2008). In fact, this possibility to combine various data sources is a particular feature of case study research and the divide between qualitative and quantitative data should not be an issue (Stoecker, 1991). In case studies, it is typical to combine different data collection techniques in various ways (Saunders et al., 2009).

To make the case as robust and convincing as possible the thesis follows three principles for data collection proposed by Yin (2009). Firstly, for triangulation data was collected from multiple sources. Secondly, a case study database was created so that any outsider could examine the data and arrive at the same conclusions as in the report. Thirdly, a chain of evidence was maintained from case study questions, to case study protocol, to citations from the database, to the case study database, and finally to the case study report, i.e. the thesis, itself.

For primary data, semi-structured interviews with open ended questions were conducted, as they are the most important source of case study information (Yin, 2009). Due to personal connections getting the specific EV charging service to participate in this case study was relatively easy. The interviews included two representatives from the platform organization itself, six EV drivers and four charging point owner representatives.

Appendix A includes the interview guide used in all 12 interviews, with varied focus between groups.

Access to the platform organization's representatives was granted by directly contacting the CBO of the company. The main focus of these interviews was gaining general information on the platform itself; who are the participants, what kind of interactions are mediated, what pricing schemes were in use, what kind of boundary resources are being used, and how is the platform structured. In addition, the interview examined interpretations on what the network effects could be, whether sides were mono- or multi-homing, how the different aspects affected the value of the platform, and if there was something else having a major influence.

The platform organization representatives had worked closely with customers on both sides of the platform. The first interviewee worked on customer success helping both sides of the platform, i.e. EV drivers and CPO's, maximize the value of the service for them. The second interviewee had worked on similar tasks previously, but had moved to focus on sales on the CPO side. Both had worked with the platform for over two years and had deep understanding of all relevant technical details.

Access to charging point owner representatives was initiated by the platform organization. Selecting potential interviewees with the help of the in-depth knowledge of the platform organization ensured all of them had sufficient experience as CPO's. An email was sent to a total of eight CPO's introducing the research project and explaining the practicalities of participation. If a reply was not received in ten days, a reminder email was sent. Two CPO's did not answer the email, two answered but declined due to scheduling issues, and a total of four agreed to participate. The main focus of the interviews was to gain insight on what were the key factors that brought most value to the CPO's.

The four CPO's had started offering EV charging mainly based on green values. The amount of charging stations ranged from two to over fifty. All representatives were generally passive participants in the service.

Access to EV drivers was arranged by the researcher using social media. There are several thriving Finnish discussion groups about EV's on Facebook. A post was sent to the most active group, "*Sähköautot – Nyt!*", explaining the research project and the practicalities of participation. A total of nine EV drivers replied stating interest or inquiring more information. Out of these six EV drivers who were affiliated with the case platform were selected. The main focus of the interviews was to gain insight on what were the key factors that brought most value to the EV drivers.

The EV drivers had chosen an EV due to green values, general interest towards new technology and superior reliability. The time they had owned an EV ranged from six months to three years, some already having their second or third EV. Their driving habits were normal, mostly based on daily commutes to work, services and hobbies.

The interviews were conducted between 22.8.2017 and 2.10.2017, 5 of them face-to-face and 7 through the online service Skype. All of the interviews were recorded, as it enables direct quoting and also enhances robustness of the study as data can be revisited (Myers, 2009). The record time of the interviews varied between 28 and 81 minutes. Appendix B includes details about all 12 interviews.

Secondary data was collected from the sales and marketing materials of the platform, customer support messages, online discussions, media texts, and the database of the platform. This data was used to build understanding on the topic and to support or question claims from the interviews.

3.4 Data analysis

A clear analytics strategy helps to follow theoretical propositions and focus the study by ignoring irrelevant data. Yin (2009) introduces five analytic techniques for case study research. Pattern matching, the first technique, is in most cases the most desirable technique and it is suitable for an intensive single case study.

In pattern matching the researcher finds patterns from collected empirical data and compares them with the theoretical propositions (Trochim, 1989). If the case is explanatory the patterns can be related to either dependent or the independent variables (Yin, 2009).

The analysis for this thesis started by transcribing the conducted interviews and by establishing a case study database with both primary and secondary data. Next, thematic analysis was used to identify themes and patterns in the data which were structured with appropriate coding (Hirsjärvi & Hurme, 2004).

Based on Eisenhardt's (1989) case study analysis process, initially each interview was analyzed separately to understand the personal views of each participant. This made it possible to understand each participant as stand-alone entities, which made cross-interview comparison more efficient.

After within-interview analysis, shared and different views were identified within embedded units of analysis in a cross-interview analysis. This analysis was conducted by utilizing categories from the academic framework.

Finally, with understanding of each embedded unit of analysis, similarities and differences were identified between the units. This cross-unit analysis helped to study the subject from different points of view to improve the reliability of the results (Eisenhardt, 1989).

3.5 Research evaluation

Kidder and Judd (1986) introduce four tests that are typically used to ensure the quality of empirical social research. The four tests are constructing validity, internal validity, external validity, and reliability. To make the case study more robust all of the tests were followed in the following way.

Constructing validity means ensuring proper operational measures, which can be particularly problematic in case studies (Kidder & Judd, 1986). To construct validity the suggested tactics were used. When collecting data several sources of evidence were used, i.e. interviews, documents, videos and discussions, and a chain of evidence was established. When composing this case study report the key informants, i.e. EV charging network organization representatives, reviewed a draft.

Internal validity means ensuring a causal link, where specific conditions lead to other conditions (Kidder & Judd, 1986). To ensure internal validity one of the suggested tactics was followed, i.e. the empirical data was analyzed with pattern matching.

External validity means ensuring a domain to which research findings can be generalized (Kidder and Judd, 1986). To ensure external validity the suggested tactic for single case studies, i.e. using theory to form a background, was used.

Reliability means showcasing that all procedures of a study can be repeated with the same results (Kidder & Judd, 1986). To ensure reliability the suggested tactics of utilizing a case study protocol and developing a case study database when collecting case data were followed.

4 Findings

The fourth chapter showcases findings from the collected empirical data. The first part describes the electric vehicle network to give a holistic overview of the case. The second part examines the service from EV drivers' perspective. The third part reviews charging point owners' (CPO) side.

4.1 The EV charging network[3]

The case service is a charging network that acts as a facilitator between charging point owners and EV drivers. In practice, the network connects the two groups in Finland.

> "*Basically we make things easy and efficient for our customers*" (EVCN 2)

For EV drivers the service offers access to charging points. They can affiliate with the network and order RFID (radio-frequency identification) tags using a registration site. They can find and reserve charging points using mobile and web applications, provided by the network or by third party providers. They can start and stop charging events with the RFID tags or with the mobile applications. They pay automatically with a credit card attached to their account. They can get support 24/7 by phone.

EV drivers are encouraged to affiliate by promoting ease of use and increased efficiency. The service provides help if needed; they do not have to separately affiliate with multiple CPO's; they get real-time information about location and availability; and they can reserve charging points in advance to avoid unnecessary trips.

For CPO's the service offers access to a charging network with an existing user base. The CPO can affiliate by purchasing a service to existing charging devices, or order a package with charging devices already connected to the network. When connected, the charging points are visible and accessible by all EV drivers; billing is automated; and the CPO's receive 24/7 customer support by phone.

CPO's are encouraged to affiliate by promoting ease of use. The service offers existing and automated processes, which make it possible for any company to offer public

[3] Unless otherwise mentioned, the information in this part is based on the interviews with two network operator representatives (August 22, 2017 & August 29, 2017), and the company website (Virta, 2017c)

EV charging. In addition, the service points out that all processes should be as automated as possible to increase efficiency, since EV charging is never the main business, and typically small money-wise.

The network enables two types of interaction. Firstly, EV drivers can control the CPO's charging infrastructure by starting and stopping charging events using an RFID tag or the applications, and pay according to the charging event. In practice EV drivers pay a prepaid sum to their user accounts, which is topped when a threshold is reached. CPO's can define a price for charging based on energy consumption and/or time. Based on charging events a corresponding sum is deducted from the EV driver's account. Payments are transferred to CPO's' bank accounts monthly.

Secondly, information is shared between EV drivers and the CPO's. From CPO to EV driver this means location, availability, charging power, price, and rating information of the specific charging points. CPO's get information about energy consumption and length of charging events, and ratings done by users, but not who charged.

Outside the service EV drivers interact with CPO's in the physical environment at the charging points. It should be noted that some information types from CPO to EV driver are available on third party applications.

Table 9 summarizes the charging network participants and the interactions between them.

Table 10: Summary of case charging network participants and interactions

Participants	Interactions
• EV drivers • Charging point owners	• Control and payments between EV drivers and CPO's, initiated by EV driver • Information exchange between EV drivers and CPO's, initiated by CPO

For EV drivers, pricing is based on a prepaid model. An initial payment is made during affiliation to be used later for charging events. EV drivers pay based on energy and time, set by the CPO. In addition, there is small monthly fee.

For CPO's, payments can be done once or monthly. The one-time investment includes access to the network for three years. With the monthly fee CPO's are engaged with the service for three years.

Access to the network is not controlled on any side, except with pricing. Interactions are controlled by the service in two ways. Firstly, information is controlled to both directions. EV drivers only get partial information about the CPO's. CPO's get only anonymous data about the length and energy consumption of charging events. This is due to a contract between the service and the EV driver. In addition, the service can control charging events, i.e. stop and start them, which is used mainly for customer support purposes when problems occur. The service is fully standardized for both sides. Only large CPO's are seen as exceptions. These key decisions made by the charging network operator are summarized in Table 10.

Table 11: Summary of charging network key decisions

Decision	**Details**
Pricing for EV drivers	• Prepaid model • Small monthly fee • Pay per use
Pricing for CPO's	• Monthly fee or advance payment for a three year access
Governing interactions	• Information controlled between EV drivers and CPO's • Charging events controlled in problem solving situations
Modularity	• Service fully standardized for both sides

4.2 Electric vehicle drivers

4.2.1 EV driver participant profile

The interviewed EV drivers were a relatively homogenous group. Most of them had chosen an EV due to green values, general interest towards new technology and/or superior reliability.

Their driving habits were normal, mostly based on daily commutes to work, services and hobbies. In addition, most reported having done a longer road trip with their EV, e.g. to Northern Finland, suggesting an experimental mindset. All participants saw themselves as forerunners.

"*As a forerunner, I'm prepared for problems. I feel like a beta tester*." (EVD 1)

Table 11 summarizes the key characteristics of the interviewees. The time the participants had owned an EV ranged from 6 months to 3 years, some already having their second or third EV. At the time of the interviews four participants owned a battery electric vehicle (BEV) and two a plug-in hybrid electric vehicle (PHEV). The ratio differs from the overall EV stock in Finland with 26 % of BEV's and 74 % of PHEV's (Trafi, 2017).

Table 12: Summary of EV driver participants' key characteristics

	EVD 1	**EVD 2**	**EVD 3**	**EVD 4**	**EVD 5**	**EVD 6**
Car type	PHEV	PHEV	BEV	BEV	BEV	BEV
Time as a EV driver	< 1 year	3 years	1 year	2 years	2 years	< 1 year
Home charging	Yes	No	Yes	Yes	Yes	Yes
Work charging	No	No	No	Yes	Yes	Yes

Private home charging was the main charging method for most interviewees. In addition, some participants were able to utilize a charging possibility at work, though this was mainly regarded as a nice extra. Only one participant relied purely on public charging points.

All of the participants used public charging networks actively. Some BEV drivers had to utilize them daily during day-to-day routines like shopping, some utilized them only on longer trips. PHEV drivers took advantage of charging actively, even though they could rely on an ICE as a backup.

4.2.2 EV driver homing

Table 13: EV driver homing

	EVD 1	**EVD 2**	**EVD 3**	**EVD 4**	**EVD 5**	**EVD 6**
Homing	Mono	Multi	Multi	Multi	Multi	Multi

All except one of the EV driver participants were multihoming with EV charging networks (Table 12), i.e. the two charging networks that are public charging networks according to Finnish legislation (Finlex, 2017).

The exception did not use the other network because it did not have technically matching charging devices, i.e. devices with a Type 2 plug without a fixed cable, around where he lived.

The main reason for affiliating with both charging networks was survival. To reach a good enough geographical coverage you had to use both networks. The charging network representatives had also introduced the same arguments.

> "*I've been a customer of both networks all the time, because the networks crisscross each other, covering different areas.*" (EVD 4)

The participants did not feel pain about the situation, but saw it more like having customer loyalty cards to both main grocery store chains in Finland, making decisions on the fly. One participant noted that having access to the other networks through roaming might change the situation. In addition, all participants used also other publicly available charging points outside the networks.

4.2.3 Effect of the number of CPO participants for EV drivers

Table 14: The effect of growth in the number of CPO participants for EV drivers

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
Orientation	Positive	Positive	Positive	Positive	Positive	Positive
Magnitude	Medium	High	High	High	High	High

The impact of the growth in the amount of CPO's was positive and big (Table 13). The amount of charging points was mentioned as the most important feature of an EV charging network by EV drivers (Table 14). It should be noted that the participant EV drivers emphasized the importance of having more charging points, and did not make a distinction between the amount of CPO's and charging points.

Table 15: Amount of charging points mentioned as the most important factors by EV drivers

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
First mention			X	X	X	
Second mention		X				X

Some participants, especially ones living in dense urban areas, had already started noticing irritating congestion, waiting for growth both in capacity in existing locations and through geographical expansion. Growth in areas that are not common for the EV driver can also be valuable, as it increases the feeling of freedom to move anywhere associated with private cars.

"*Overall it's a positive feeling if we get more chargers, even though I would never use them.*" (EVD 3)

This general view was shared by most EV drivers. However, one of the participants was critical about irrelevant locations.

"*So many times I've gotten disappointed when I hear about new chargers in small towns I've never heard of.*" (EVD 2)

As an optimal solution one EV driver described a network in which he would not have to check any map when traveling to a new area, but in which he could assume that a certain type of area would have charging points by default.

Also, the EV charging network representatives saw the amount of charging points as the most crucial feature affecting EV drivers. They stated that EV drivers typically start their comparison by examining the density of the network around their typical commutes. They also added that the more charging points there are, the more EV drivers there will be in general, not just as customers of the service.

However, most EV drivers critically noted that it is not purely about quantity, but also the quality of the growth. All participants paid attention to the technical specifications of new charging points, the location's relation to their typical routes, and the services nearby the charging point. One participant mentioned a swimming hall and a funeral parlor as real-life examples of suboptimal locations for fast charging devices.

"*I choose where to stop for shopping and eating based on available charging points*." (EVD 4)

4.2.4 Effect of the number of EV driver participants for EV drivers

Table 16: The effect of growth in the number of EV driver participants for EV drivers

	EVD 1	**EVD 2**	**EVD 3**	**EVD 4**	**EVD 5**	**EVD 6**
Orientation	Positive	Negative	Positive	Positive	Positive	Negative
Magnitude	Low	Low	Low	Medium	Medium	Low

The impact of the growth in the amount of EV drivers was mainly positive, but relatively smaller than with the amount of CPO's (Table 15). This was due to two reasons.

Firstly, most participants had an EV due to green values and saw more EV's as a generally a good thing. It should be noted that this is most likely not the case with the general population.

Secondly, most participants saw the improvements in the service level as the main reason behind the positive orientation. The reasoning was that the more EV drivers there are in the network, the more charging points there will be due to increased demand, and thus the service becomes better for them as well.

> "*I'm confident that we get more chargers and better service when there's more EV drivers*." (EVD 3)

This view was also shared by the both EV charging network representatives, who suggested that also social proof has a big impact with these new services. One EV driver saw the situation analogous to other industries, and pointed out that the service level of celiacs got better when the general population got excited about gluten-free foods.

It should be noted that regarding the attitudes towards the amount of EV drivers, PHEV and BEV owners are in a somewhat different situation. If there is congestion due to growth in the number of EV drivers, PHEV drivers can simply use their petrol engines to extend their range.

Even though at the time of the interviews the EV drivers saw the growth on the same side as a positive issue, some of them were concerned about the future. They saw that especially BEV's with a small battery might see a fall in the service level due to congestion.

One participant noted that already the most popular spots were experiencing almost 100 % utilization rates during daytime. The negative views were fueled by stories about bad experiences in Norway, where EV stock was almost 100 times bigger compared to Finland (EAFO, 2017a).

> "*When driving on a motorway you see another BEV in the mirror, and you know the car type, the battery size and that there's just one fast charger on this route, you suddenly become fierce enemies.*" (EVD 2)

4.2.5 Importance of reliability for EV drivers

Table 17: Reliability mentioned as the most important factors by EV drivers

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
First mention		X				
Second mention	X		X	X		

Reliability was mentioned as the second most important feature of an EV charging network by EV drivers (Table 16). All had at some point had problems with public charging devices. Many felt anxious especially about fast charging on longer trips and had fears if the chargers would actually work.

> "*If you say there's a charging point somewhere, then you should be able to charge.*" (EVD 2)

Around the clock customer service was seen as an important feature, as it improved the feeling of reliability. All participants had communicated with a customer service by phone and were pleased with the help they got.

Reliability as one of the main issues was also suggested by both network representatives. They added that the network operator should emphasize an image of professionalism with wide industry knowledge to build trustworthiness.

4.2.6 Importance of user experience for EV drivers

Table 18: User experience mentioned as the most important factor by EV drivers

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
First mention	X					X
Second mention					X	

User experience was mentioned as the third most important factor affecting the value of the EV charging network by EV drivers (Table 17). Finding charging points and starting charging events should be as easy as possible. This affects the behavior of EV drivers heavily (Table 18).

Table 19: Summary of EV driver participants' charging habits

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
Checks availability	Yes	Rarely	No	Rarely	No	Yes
Uses reservation	Yes	No	No	No	No	No
Uses 3rd party apps	Yes	Yes	Yes	Yes	Yes	Yes
Owns RFID tags	No	Yes	Yes	Yes	Yes	Yes
Main method for charging	Mobile app	RFID	RFID	RFID	RFID	RFID

Checking charging point availability in advance on mobile and web applications was seen painful, and most EV drivers do not do it. One of the participants who does it regularly feels it is annoying, but does it anyway due to bad experiences with malfunctioning devices. However, many think the availability status will become relevant in the next few years.

> "*I probably need to start checking availability in the future as we get more electric vehicles on the road*." (EVD 4)

Reserving a charging point was also seen as an unnecessary feature - for now. Only one of the participants reported using the feature regularly.

"*I think it's good to signal others about my intentions*." (EVD 1)

The main disadvantage in checking availability in the applications by the networks was the amount of charging points shown. These applications offer information about only the charging points connected to the networks. This had lead all of the participants to using third party applications, like PlugShare and ChargeMap. These applications aggregate crowdsourced charging point data regardless of the network. These applications were used especially for route planning.

The mobile applications offered by the charging networks were seen as hard and slow to use. The EV drivers felt that the user experience in them was lacking, that it took too many clicks to start charging and that there was too much learning in them. The mobile applications were seen as a last, backup option for starting charging events.

"*I shouldn't have to take my phone out. It's definitely a pain*." (EVD 2)

In contrast, RFID cards and tags offered by the charging networks were seen as easy to use. Consequently, most participants used RFID as the main method for charging.

The findings from the interviews are somewhat conflicting with actual data from actual charging events, but also supported by a customer questionnaire. In the previous 10 000 charging events, out of all events charging was started 54 % with an RFID and 42 % with the mobile application. The remaining 4 % were initiated with a SMS or credit card payment.[4] In a questionnaire sent to all EV driver customers (n=155), the main methods for initiating charging events were RFID for 67.7 %, mobile application for 22.6 %, and both RFID and mobile application for 9.7 % of respondents.[5]

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[4] Data from 10 000 previous charging events in Finland. Retrieved on 15th of September 2017 from the network database.

[5] Data from an EV driver questionnaire sent by email and social media to all EV driver customers. Data collected between 12th and 19th of October 2017.

In addition, the physical environment affected the user experience. Some participants reported having difficulties finding charging points in big parking halls. In addition, one of the participants preferred charging points with fixed cables.

"*I hate getting my muddy charging cable from the trunk, so I prefer fixed cables*." (EVD 5)

4.2.7 Effect of pricing for EV drivers

Table 20: Effect of pricing on EV drivers' behavior

	EVD 1	**EVD 2**	**EVD 3**	**EVD 4**	**EVD 5**	**EVD 6**
Effect of pricing	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Small impact

Pricing was seen as an irrelevant factor by all participating EV drivers (Table 19). The prepaid payment was thought to be somewhat irritating, but not relevant in the bigger picture. Similarly, the small monthly fee was regarded as a small nuisance, but compared to the value it brought it was not an issue.

As most participants were multihoming, they were also posed with the question about which charging point to choose. The price of charging varies between charging point owners and charging networks, but in practice there is no freedom of choice, but just one choice per location. Due to this fact price of charging was seen irrelevant.

"*Pricing is not relevant because there's no choices. The only charger in town is what I choose, whatever it costs*." (EVD 2)

The attitudes are explained by the relatively low fuel costs, which can be three times lower compared to similar fuel-efficient ICE vehicles (Consumer reports, 2011).

The views of the participant EV drivers conflicts with the network representatives. The operators think that the prepaid model with a monthly fixed fee heavily discourages EV drivers. The view is based on discussions on social media and might be the case with EV drivers who have not affiliated with the service.

4.2.8 Effect of interaction control for EV drivers

Table 21: Effect of interaction control on EV drivers' behavior

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
Effect of information control	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
Effect of charging control	Positive	Positive	Positive	Positive	Positive	Positive

The EV charging network governs interactions in two ways (Table 20). Firstly, it controls charging events in problem situations. This was seen as a positive feature by all participating EV drivers, as it makes it possible for the operator to help EV drivers for example when the charging device does not work. Understanding the feature increases the feeling of reliability and trustworthiness.

Secondly, the service controls information flow between the participants. Most participants felt that they get enough information from the CPO side, and did not see additional information like the source of electricity relevant. The EV charging network representatives share the same views as the EV drivers regarding governance issues.

4.2.9 Effect of standardization for EV drivers

Table 22: Effect of standardization on EV drivers' behavior

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
Effect of standardization	Positive	Positive	Positive	Positive	Positive	Positive

The standardization of the service was seen as a highly positive feature. Most did not care if additional features or parallel service packages existed, but did not see a demand for them. Only fixed monthly price packages were suggested, as they could serve as positive indicators of fuel costs for non-EV drivers.

"*Simple is good*." (EVD 3)

4.2.10 Summary of key value contributing factors for EV drivers

Table 23: Summary of most important factors in an EV charging network for EV drivers

	EVD 1	EVD 2	EVD 3	EVD 4	EVD 5	EVD 6
First	User experience	Service reliability	Number of charging points	Number of charging points	Number of charging points	User experience
Second	Service reliability	Number of charging points	Service reliability	Service reliability	User experience	Number of charging points

When asked what the participant EV drivers saw as the two most important factors in an EV charging networks, they mentioned only three factors (Table 22). Firstly, number of charging points got five mentions. This clearly indicates the importance of a comprehensive network with sufficient geographical coverage. Secondly, service reliability got four mentions. This indicates that EV drivers want a reliable experience for efficiency. Thirdly, user experience got three mentions, indicating the need for a minimized and painless experience for efficiency.

4.3 Charging point owners

4.3.1 CPO participant profile

The charging point owners had started offering EV charging as a value-added service for the same reason: the companies wanted to promote their green values by being a forerunner in supporting emission-free transportation.

> "*We understood from the very beginning that EV charging is not a way to make money, but to promote EV's in our area and the green values of our company.*" (CPO 3)

They were all also explicit about understanding the service as a marketing tool, not as a significant source of revenue. This meant they did not want to invest a lot of time and effort, but rather wanted to have all processes as automated as possible.

Table 23 summarizes the key characteristics of the interviewees. Most of the interviewed CPO's reflect the development of the industry, as they had started offering EV charging within a year. The amount of charging points ranged from 4 to 55. Half of the CPO's operated in the property management and half in the energy industry.

Table 24: Summary of CPO participants' key characteristics

	CPO 1	CPO 2	CPO 3	CPO 4
Amount of charging points	6	2	4	55
Time as a CPO customer	< 1 year	< 1 year	< 1 year	3 years
Main industry	Property management	Property management	Energy	Energy
Interviewee position	Project manager	Technical manager	Development director	Technical manager

4.3.2 CPO homing

Table 25: Charging point owner homing

	CPO 1	CPO 2	CPO 3	CPO 4
Homing	Mono	Mono	Mono	Mono

All of the participants were mono-homing with EV charging networks, i.e. the two charging networks that are public charging networks according to Finnish legislation (Table 24; Finlex, 2017).

The main reason behind mono-homing was efficiency. The CPO participants felt using several services would multiply their workload. EV charging was considered to be a small side service, so the participants tried to minimize the resources allocated for it. All of the CPO's said that they are already using so many different services in other areas that even one more feels like a burden.

> "*One system for public EV charging is enough, because efficiency matters in the day-to-day.*" (CPO 4)

The reasoning was also shared by the EV charging network representatives. They stated that CPO's choose one and stick with it to make things easy and efficient, and that there is too much trouble using several systems. Mono-homing might also become a competitive advantage for larger CPO's, as stated in a customer case.

> "*Hesburger wants the service experience be the same everywhere, also with EV charging*." (Virta, 2017b)

In addition, one of the CPO participants noted that as the industry is fairly new, they find it important to commit to one service provider and co-develop the offering based on their needs.

4.3.3 Effect of the number of CPO participants for CPO's

Table 26: The effect of growth in the number of CPO participants for CPO's

	CPO 1	**CPO 2**	**CPO 3**	**CPO 4**
Orientation	Positive	Positive	Positive	Positive
Magnitude	High	High	High	High

The amount of charging points was an important factor for all CPO's, especially if the other CPO's were located in the same geographic area (Table 25). As EV charging was not considered to be a core business or a significant source of revenue, the participant CPO's were not threatened by competing charging points. Like with EV drivers, the CPO participants emphasized the importance of charging points, and did not make a distinction between the amount of CPO's and charging points.

The reasoning behind the positive attitude was thinking about the end user experience.

> "*It's good for our customers that they can use the same account at our charging points and in other places. We emphasize the user experience of our customers*." (CPO 1)

The EV charging network representatives agree that the CPO's evaluate the services from the EV drivers' perspective. This is why the network representatives argue that having the biggest network in the CPO's geographic area has the biggest effect on decision making.

The network representatives also add that social proof plays a significant role. They argue that having more charging points makes the service seem more reliable, at least by creating more pressure for the system operator.

4.3.4 Effect of the number of EV driver participants for CPO's

Table 27: The effect of growth in the number of EV driver participants for CPO's

	CPO 1	CPO 2	CPO 3	CPO 4
Orientation	Neutral	Neutral	Neutral	Neutral
Magnitude	Low	Low	Low	Low

For the participant CPO's the amount of EV drivers in the network or overall does not have a major influence (Table 26). The transition from ICE vehicles to EV's was seen as inevitable, and based on their green values the CPO's want to prepare for the shift.

Based on this mindset all participants understood that there was not going to be a lot of usage for the charging points at this point in time. The main focus of the service was using it as a marketing tool to concretely communicate the green values of the organization. It should be noted that even though the amount of EV drivers did not play a major role in the decision making of the CPO's, all of them were prepared to scale up if there would be a lot of demand in a specific location.

In contrast, the participant CPO's focused on the amount of charging points in the networks.

> "*We didn't consider how much the service had registered customers, but rather concentrated on the amount of charging points.*" (CPO 1)

The views of the CPO's were aligned with the comments by the EV charging network representatives. They noted that it is typically not clear for the CPO how many EV drivers there are as customers of the service, or in general. They also said that CPO's are also somewhat passive in monitoring the demand of their EV charging services. However, they also added that in initial sales negotiations the CPO's always ask about the amount of EV drivers, and that there seems to be a positive correlation with the amount of CPO's and EV drivers in general.

The network representatives also emphasized the importance of the marketing perspective. They said that the most important thing for the CPO's is promoting their companies through the service. The view is also shared by a customer in a reference article.

> "*For Hesburger environmental issues are important and charging points are a natural way to showcase the values*." (Virta, 2017a)

4.3.5 Effect of reliability for CPO's

Table 28: Reliability mentioned as the most important factors by CPO's

	CPO 1	CPO 2	CPO 3	CPO 4
Mentioned	No	No	No	No

The network representatives argued that the second most important factor for CPO's is reliability. They stated that the CPO's care if the network organization seems like it knows what it is doing and is relevant also in the long-term. However, these issues did not arise in the interviews with the CPO's in the same way as with the EV drivers (Table 27). Rather, the CPO's were more focused on the user experience of the service.

4.3.6 Importance of user experience for CPO's

Table 29: User experience mentioned as the most important factor by CPO's

	CPO 1	CPO 2	CPO 3	CPO 4
First mention	X	X	X	X
Second mention	X		X	X

Efficient user experience was the main theme in all of the interviews with the participant CPO's (Table 28). They also paid attention to the EV driver user experience. All participants were already using several other services for various purposes, so minimizing interaction was seen crucial.

> "*As a property manager I counted having around 30 different services and applications.*" (CPO 2)

This thinking has lead to a situation where the CPO’s do not want to actively manage anything. For now most of them have mainly set pricing and other initial parameters and did not actively use the software provided.

The CPO’s felt that the service should run smoothly in the background without any effort, including automated payments and maintenance. Some participants advocated for comprehensive maintenance, which was not included in the service.

“*I don’t want an easy turnkey solution. I don’t want the key at all.*” (CPO 1)

The network representatives did not emphasize CPO user experience in any way. However, the view was explicit in a customer case on the service’s website.

“*For Hesburger it was essential that the charging points don’t bother the staff.*” (Virta, 2017a)

4.3.7 Effect of pricing for CPO’s

Table 30: Effect of pricing on CPOs’ behavior

	CPO 1	**CPO 2**	**CPO 3**	**CPO 4**
Effect of pricing	Low impact	Low impact	Low impact	Low impact

The participant CPO’s did not consider price a significant factor in their decision making (Table 29). A smooth user experience mattered more than pricing. Pricing mattered only if it varied significantly compared to competition. As all CPO’s were companies they saw transparency to future pricing important for budgeting reasons.

“I rather pay a bit more and have things run smoothly. In the real estate industry it’s typically more expensive to buy the cheapest option.” (CPO 2)

The EV charging network representatives offer a similar view and argue that as a new service it is hard for the CPO’s to assess pricing. They note that because of this pricing needs to be relatively close to competition, but otherwise it does not have a major effect.

4.3.8 Effect of interaction control for CPO's

Table 31: Effect of interaction control on CPOs' behavior

	CPO 1	**CPO 2**	**CPO 3**	**CPO 4**
Effect of information control	Not relevant	Not relevant	Not relevant	Not relevant
Effect of charging control	Positive	Positive	Positive	Positive

The participant CPO's do not use the service actively. They all feel that there is enough information available, and that the control over information did not have any effect on their decisions (Table 30). The EV charging network representatives agree and add that as a side service they do not need more data about EV charging.

> *"I've actively been taking part in the implementation of GDPR, so I understand we have no right to get personal information about EV drivers. And we don't really need them."* (CPO 3)

The service's control over charging events was seen as a highly positive factor, as it meant less work for the CPO's. The network representatives agree.

> *"Control is a good thing. Anything that is less work for us is good"* (CPO 2)

4.3.9 Effect of standardization for CPO's

Table 32: Effect of standardization on CPOs' behavior

	CPO 1	**CPO 2**	**CPO 3**	**CPO 4**
Effect of standardization	Positive	Positive	Positive	Positive

The standardization of the service offering was seen as a highly positive factor, as the participant CPO's did not want to use resources to study what service would suit them (Table 31). Overall standardization increased efficiency.

"If the service is diversified you get more questions, twists and turns, which lead to more pain." (CPO 2)

The EV charging network representatives continue that as EV charging is a new service and not a core business for most, simplifying decision making has a positive effect.

4.3.10 Summary of key value contributing factors for CPO's

Table 33: Summary of most important factors in an EV charging network for CPO's

	CPO 1	CPO 2	CPO 3	CPO 4
First	CPO user experience	EV driver user experience	CPO user experience	EV driver user experience
Second	EV driver user experience	Long-term viability	EV driver user experience	CPO user experience

When asked what the participant CPO's saw as the two most important factors in an EV charging networks, they mentioned only three factors (Table 32). Firstly, user experience for EV drivers got four mentions. This clearly indicates that CPO's emphasize the EV driver perspective in their decision making. Secondly, user experience for CPO's got three mentions. This indicates the need for a minimized and painless experience for efficiency. Thirdly, long-term viability got one mention. This indicates high perceived switching costs and the need for efficiency.

5 Analysis

This chapter showcases key results from analyzing the empirical findings by matching them with the theoretical framework.

Firstly, there was a need to find out how the case EV charging network is structured and whether it can be described as a multi-sided platform. Secondly, there are two key factors affecting the value of the charging network, i.e. the amount of charging points and efficiency. These factors are discussed in separate parts. Thirdly, a revised theoretical framework is built based on the analysis.

5.1 EV charging network as a two-sided platform

Business models in the EV charging industry vary from completely open multi-sided platforms (MSP) to completely closed vertically integrated services. Despite this the term platform is widely used by almost all service providers. To fully understand if academic research about MSP's can be applied in the context of the case, there is a need to analyze how the case network is structured and whether it is a MSP.

5.1.1 Multi-sided platform definition

Based on the definition by Hagiu and Wright (2011) the case EV charging network is a multi-sided platform as it meets all requirements.

Firstly, the case organization primarily focuses on enabling direct interactions between the two sides. This is for example clear in the main statements in the marketing materials of the charging network.

> "*You can offer EV charging publicly or privately. As an EV driver you gain access to the biggest charging point network in Finland*." (Virta, 2017c)

Secondly, the case network allows the direct interactions to be fully controlled by the participant. Communication is free from intervention as the information shared can be freely set by the CPO based on parameters set by the network operators. Exchange is free as CPO's can set pricing without restrictions. Consumption is free as EV drivers can use any charging point according to availability.

Thirdly, the case network enables three interactions: communication of location, availability, power, price and rating information from a CPO to an EVD; consumption of energy by starting a charging event as an EVD; and exchange of money based on charging events between a CPO and an EVD.

Fourthly, both CPO's and EVD's consciously affiliate with the case network, as both have to make a fixed investment when joining.

Fifthly, the customer type, i.e. a CPO or an EVD is distinct at the point of interaction, as individuals and organizations can be both at the same time and take the role when using the case network.

5.1.2 EV charging network structure and interactions

The earlier research suggests that an EV charging network has three sides (EV owners, EV; charging point managers, CPM; the energy system, ES), and enables three transactions between them (information from CPM to EV; control and payments from EV to CPM; and V2G services with payments from EV to ES)[6].

The case EV charging network reflected these suggestions partly. The network included EV drivers and CPO's as sides, and enabled the suggested transactions between them. However, the network did not offer the suggested V2G transactions to the energy system side commercially at the time of the study. There were also no signs of other network operators offering such services. Thus, the energy system as a third side with related interactions is currently irrelevant.

However, this area is likely to become relevant in the long-term, in the third development phase described by San Roman et al. (2011). There were already signs of such development by the case platform in the form of an industrial pilot project with a local energy utility (Helen, 2017).

In addition, the theoretical framework suggested that one of the interactions is availability information from CPO to EV driver. However, based on the empirical data there is also other information being conveyed from CPO to EV driver, e.g. charging power, access, location and rating.

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[6] Unlike suggested by San Roman et al. (2011), the terms EV driver and charging point owner (CPO) are widely used in the industry instead of EV owner and charging point manager (CPM), and thus are used when describing the case in this thesis.

Based on the analysis the revised EV charging network structure consists of two sides, i.e. EV drivers and CPO's, and two interactions between them, i.e. information from CPO to EV driver, and control and payments from EV driver to CPO (Figure 12).

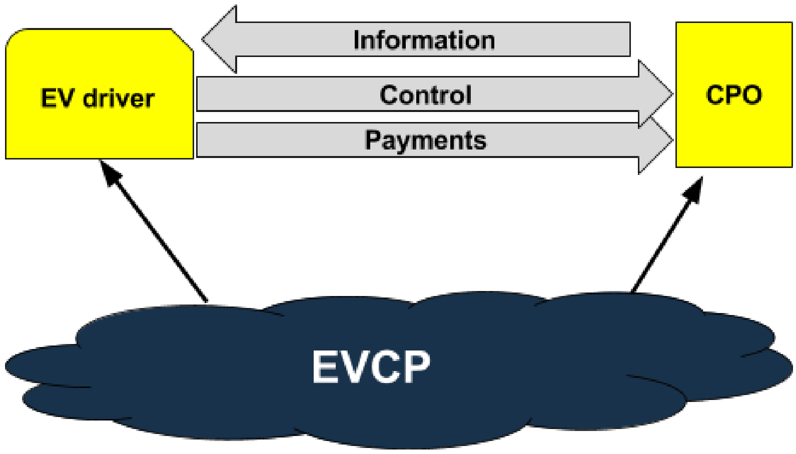

Figure 12. Revised EV charging network structure and interactions

5.2 Number of charging points as the main target

Charging points are the core element bringing value to EV charging network participants. Studying the case network revealed three supporting factors.

Firstly, growth in the number of charging points was the most important factor for EV drivers. Secondly, EV drivers had to multihome to survive. Thirdly, growth in the number of charging points was a significant factor for CPO's.

5.2.1 EV drivers' positive cross-side network effect

The first phenomenon signaling the importance of the number of charging points is EV drivers' positive cross-side network effect. The number of charging points was the most important factor for all participating EV drivers.

Like the theoretical framework suggests, the number of CPO's should have an effect on the value of the network for participants. It should be noted that this theoretical suggestion is linked to the number of participants, i.e. CPO's, and not their assets, i.e. charging points.

A network effect is the impact of the change in the number of participants on the value of a network participant (e.g. Armstrong, 2006). Since the amount of CPO's correlates strongly with the amount of charging points, the link between positive attitudes towards the amount of charging points can be regarded as a positive cross-side network effect. However, it is important to understand that from the EV drivers' perspective it is irrelevant if growth comes from more CPO's or from CPO's acquiring more charging points.

In addition, EV drivers emphasized the importance of charging point location quality. In practice, this means that not all growth is valuable, but factors like technical features (e.g. charging power, plug type and device manufacturer), geographic location (relative to typical routes) and service offering (e.g. shops and restaurants) have a positive or negative impact.

5.2.2 EV driver multihoming

As the second phenomenon, the multihoming of EV drivers further indicates the importance of the number of charging points. The main reason for multihoming was mere survival, since no network offered sufficient geographical coverage.

The finding is contrary to what previous research suggests. San Roman et al. (2011) suggests that EV drivers might benefit economically and have a better user experience when retaining a relationship with only one EV charging network. The suggestion might hold true in the future in a more mature market, but in the case context it was clear that multihoming was necessary.

To conclude, multihoming itself is not a factor to be emphasized. Rather, it is a phenomenon that indicates something else, in this case the importance of a sufficient charging point network. As the EV charging market develops, homing is a metric to be tracked, as the industry dynamics might change significantly if multihoming is no longer necessary.

5.2.3 CPO's positive same-side network effect

The third phenomenon indicating the importance of the number of charging points is CPOs' positive same-side network effect. The number of charging points was an important factor for CPO's, though with a relatively smaller impact compared to EV drivers.

As stated previously, the theoretical framework suggests a link between the number of CPO's and the value of the service for CPO's. It should be noted that this theoretical suggestion is linked to the number of participants, i.e. CPO's, and not their assets, i.e. charging points.

A network effect is the impact of the change in the number of participants on the value of a network participant (e.g. Armstrong, 2006). Since the amount of CPO's correlates strongly with the amount of charging points, the link between positive attitudes towards the amount of charging points can be regarded as a positive same-side network effect.

The argument is further supported by CPOs' emphasis on the importance of geographic proximity. They preferred adding to an existing charging point network in the area they operated, not being the first mover.

5.3 Efficiency with boundary resources and architecture

In addition to the number of charging points, both sides strove to maximize efficiency. For EV drivers, charging was something mundane, a pain that should be minimized. For CPO's, EV charging was a small value-added service, in which charging itself was not the main focus, but rather benefits like increased awareness among their customers. The empirical data suggests that boundary resources and architecture should be used to maximize efficiency of the service.

There are five factors supporting the claim. Firstly, CPO's were monohoming to minimize interaction with EV charging services. Secondly, a standardized offering was seen as the foundation for efficient interaction. Thirdly, the network's control over interactions was regarded to increase efficiency significantly. Fourthly, there was a need to design the CPO interface to increase efficiency. Fifthly, there was a similar need for EV drivers' interface.

5.3.1 CPO monohoming

As the first factor, the monohoming of CPO's indicates a need for an efficient experience, as efficiency is the most important factor affecting homing (Evans, 2003). Efficiency was the main reason behind monohoming, as using multiple networks would multiply the workload for CPO's.

Previous EV charging research does not comment on CPO homing. However, as the EV charging market develops and CPO's become affiliated with roaming networks, the dynamics behind homing might change drastically, as EV drivers from other networks are able to access the network of a CPO.

To conclude, monohoming itself is not a factor to be emphasized. Rather, it is a phenomenon indicating something else, in this case the importance of efficiency.

5.3.2 Standardized and simplified architecture

As the second factor, network access for both CPO's and EV drivers was fully standardized, i.e. the service was identical between participants on the same side. This standardization was seen as a positive factor by both sides, as it made the affiliation process more efficient.

Earlier research suggests that in the long-term platforms should create an open modular architecture, as the design opens opportunities for new value to be created (Ethiraj et al., 2008; Parker et al., 2016). A modular design allows for specialization, that increases operational efficiency (Thomas et al., 2014; Tiwana et al., 2010).

In the context of the case it is clear that at this point in time there is no need for such new opportunities. None of the participants had any needs beyond what was already offered. As a novel industry, there was enough value in the core functionalities, and too many new interactions can lead to too much complexity, which can be harmful (Parker et al., 2016).

To conclude, in the initial phases of the industry a standardized design creates value by increasing efficiency. However, a modular structure is likely to become relevant as the industry matures and the need for differentiation with complementary innovations increases.

5.3.3 Controlling interaction with boundary resources

As the third factor, there was a clear need to control interactions with boundary resources to maximize efficiency. Boundary resources are typically used to minimize costs linked with network externalities, like asymmetric information, complexity and uncertainty (Boudreau & Hagiu, 2008).

The theoretical framework suggests that boundary resources have an effect on participant value. Boundary resources are used to control affiliation and interactions on a platform (Ghazawneh & Henfridsson, 2013). The case EV charging network controlled interactions to reduce complexity and uncertainty.

Firstly, the network controlled information flow between the two sides. Control was done with both technological and legal boundary resources. For EV drivers, the goal was to protect personal information, which was not distributed to the CPO due to privacy concerns. For CPO's, the goal was to reduce complexity, since in a new industry they had no experience on what information to convey. Information control was seen as a neutral, or slightly positive, factor by both EV drivers and CPO's. They regarded the issue as insignificant and were pleased with the amount of information available.

Secondly, the network controlled charging events between the two sides. Control was done with technological boundary resources in situations requiring problem solving. For EV drivers, the goal was to decrease uncertainty, since getting stuck was literally a major problem. For CPO's the goal was to minimize input by solving problems remotely for them. Charging events control was seen as a highly positive factor by both EV drivers and CPO's. Most EV drivers had personal experiences about such control, and they felt the feature increased efficiency in problem situations. CPO's were pleased that the feature eliminated the need for problem solving by their organizations in most situations.

5.3.4 Other boundary resources on the CPO side

As the fourth factor, there was a clear need to optimize the use of other boundary resources on the CPO side to tackle reliability issues and to increase efficiency in CPO user experience. Like stated previously, the theoretical framework suggests a link between boundary resources and platform value for participants.

Firstly, EV drivers heavily advocated the need for increased reliability to maximize efficient use of the network. The lack of reliability caused pain for the EV drivers, as they felt they could never trust if a charging point worked or not. Problems with charging devices affect efficiency negatively, often multiplying the time and effort charging a vehicle takes. In worst cases problems can make the vehicle unusable.

EV charging networks should increasingly utilize boundary resources to minimize uncertainty. Understanding what type of instruments should be utilized requires further research, but they could be legal, e.g. penalizing malfunctioning charging points, or technological, e.g. improving forecasts of problems.

Secondly, CPO’s heavily advocated the need to minimize interactions with the platform. The aim for all CPO’s was to have a completely painless user experience with as little interaction as possible to maximize efficiency. EV charging was not the main business, but rather a small side venture, so all resources allocated for it should be minimized.

EV charging networks should increasingly optimize boundary resources to minimize interaction with the service. Understanding what type of instruments are optimal requires further research, but e.g. technological instruments could further automate processes, and cooperative instruments could let CPO’s help each other.

5.3.5 Other boundary resources on the EV driver side

As the fifth factor, there was a clear need to optimize other boundary resources to make the EV driver user experience as painless as possible. The goal is to decrease interaction with the network to increase efficiency. Like stated earlier, the theoretical framework implies that boundary resources can affect network value for EV drivers.

The need for a smooth user experience for EV drivers was explicit throughout the findings. It was advocated by both EV drivers and by CPO’s, who had taken the end user experience into account in their decision making.

The need for EV drivers’ to minimize interaction with the network was evident in their charging behavior, e.g. as they rarely checked for availability or reserved a charging point; as they utilized third party applications to maximize information per interaction; and as they mainly used RFID cards to initiate charging events. Efficiency was important, because starting and stopping charging does not provide any value itself, but rather is a mundane and mandatory task.

EV charging networks should increasingly optimize both current, e.g. mobile applications, and future boundary resources for minimized interaction. New instruments could be introduced to further minimize input. However, understanding what these instruments could be requires further research.

5.4 Revised theoretical framework

A theoretical framework, built on existing platform economics and EV charging research, was proposed in the Literature review chapter. The framework was used in this Analysis chapter by finding patterns in empirical data and matching these patterns to the theoretical framework. The theoretical framework proved to be useful and hold somewhat true. However, there are issues that demand a revision for the framework.

The theoretical framework proposed that there are six factors affecting the value of an EV charging network for its participants: architecture, pricing, boundary resources, number of EVD participants, number of CPO participants and number of energy system participants. Based on the findings from the empirical data there is a need to refine this suggestion.

Firstly, it should be noted that all significant factors affect both sides, i.e. EV drivers and CPO’s. The intensity of the effects might differ, but as quantifying impact is out of the scope of this thesis, there is no need to differentiate the sides.

Secondly, based on the analysis the amount of charging points is the most important factor for both sides. The theoretical framework suggested that the amount of CPO’s would matter, but based on the analysis both sides are only interested in the amount of assets the CPO’s hold.

Thirdly, boundary resources towards both sides are increasingly important in maximizing efficiency and thus providing value for participants. Based on the analysis it is impossible to pinpoint the exact boundary resources that bring value. Interestingly boundary resources used for one side affect the value of the other side significantly. For example, boundary resources used to improve reliability on the CPO side affect the value of the platform for EV drivers, and boundary resources used to improve user experience on the EV driver side affect the value of the network for both CPO’s and EV drivers.

Fourthly, architecture, most notably modularity, has significance in improving efficiency and thus providing value for both sides. Even though quantifying the impact requires further research, the empirical data clearly indicates that architecture is relatively less important than the amount of charging points or boundary resources.

Fifthly, the number of EV drivers had a small impact on the value of the network for both sides, but the intensity was relatively low, and in some cases insignificant or even slightly negative. Most importantly, due to lack of information, both sides made no distinction between EV drivers as network participants and EV drivers in general, so the factor can not be regarded as a feature of the charging network.

Sixthly, based on the analysis pricing had no significance for any side on the network. This interesting finding is somewhat contrary to earlier platform research, which emphasizes the role of pricing in e.g. using skewed pricing schemes to lure participants on one side (e.g. Eisenmann et al., 2006). For EV drivers there was a somewhat clear reasoning visible in the empirical data; pricing did not matter, because of the immature market there was no possibility for selection, and because the price of fueling an EV was significantly lower than fueling an ICE vehicle. For CPO's the reasoning was not as clear and requires further research.

Seventhly, as stated previously, the EV charging network did not connect any energy system players with V2G services, so the number of energy system participants becomes insignificant. However, in future research the factor might become relevant.

The revised framework includes five factors that have an effect on the value of the network for EV drivers and CPO's. Figure 13 summarizes the factors in relative order of importance.

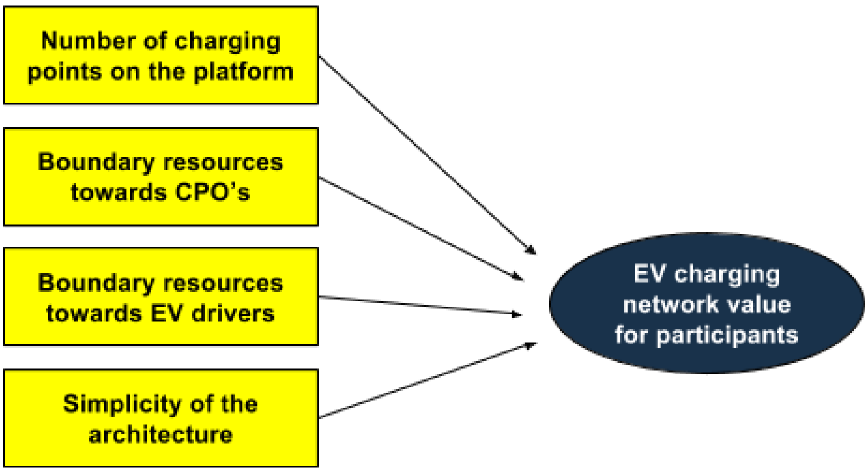

Figure 13. Revised factors affecting the value of the network for EV drivers and CPO's

6 Conclusion

The goal of this thesis, set in the Introduction chapter, was to find out how an EV charging network can succeed. To achieve this goal, there was a need to understand what factors are significant in bringing value to the participants. Thus, the research question of this thesis was:

What factors contribute to the value of an EV charging network for its participants?

To answer this research question, this thesis examined earlier platform economics and EV charging research, and applied theoretical suggestions to a real-life situation. This helped to explain the EV charging network, with its structure, participants and their interdependencies, and to identify factors that are significant in adding value for participants.

This chapter concludes the research conducted for this thesis by summarizing both theoretical and empirical findings. The chapter includes five parts. Firstly, main findings of the case study are explicated. Secondly, the findings are examined in the theoretical context. Thirdly, the findings are examined in the managerial context. Fourthly, limitations of this study are discussed. Fifthly, suggestions for further research topics are introduced.

6.1 Main findings

The findings in this thesis clearly indicate that the EV charging industry is still in its infancy, and that there is a lot of room for improvement. It is also clear that the findings showcased here are bound to time, and provide a snapshot of the industry at a specific moment like suggested by Stoecker (1991).

This thesis sought to understand EV charging networks by applying existing platform research to a real-life situation. It became evident that that concepts related to multi-sided platforms can be applied to EV charging networks, if criteria proposed by e.g. Hagiu & Wright (2011) are met. This opens EV charging networks to new interesting research topics.

The findings from the theoretical and empirical analysis indicate two factors related to EV charging network structure.

Firstly, currently during the second development phase of the industry proposed by San Roman et al. (2011), the network consists of two sides and two interactions between them. On one side, charging point owners (CPO) can transfer information about their charging points to EV drivers. On the other side, EV drivers can start and stop charging events on these charging points and transfer payments to CPO's.

Secondly, as San Roman et al. (2011) suggests and as various V2G related studies indicate (e.g. Guille and Gross, 2009; Mwasilu et al., 2009; Lund and Kempton, 2008), connecting the existing sides to a third side, the energy system, i.e. suppliers, transmission and distribution system operators, is likely to become become relevant and even a significant competitive advantage. This change is likely to affect the dynamics of EV charging networks significantly.

The main objective of this thesis was to understand the factors that bring value to network participants. It is clear that the findings do not suggest any winning recipe, but rather pinpoint focus areas. Understanding the exact factors requires further research, discussed later in this chapter. The findings from the theoretical and empirical analysis pinpoint two focus areas that can help EV charging networks succeed.

Firstly, the main contributor to the value of an EV charging network is the amount of charging points connected to it. This is mainly due to EV drivers' strong positive cross-side network effects and to CPOs' strong positive same-side network effects.

Secondly, the charging network, its architecture and boundary resources, need to be designed to maximize efficiency for both CPO's and EV drivers. For EV drivers charging an EV is a mundane task that needs to be as effortless as possible. For CPO's offering EV charging is not a main business, but rather something they want to have without any effort.

These main findings show that the research objectives set out earlier were clearly reached, with the help of both a theoretical framework and empirical data.

6.2 Theoretical contributions

Theoretically this study is a first step towards a new research area. This thesis serves as a starting point for a new research stream, converging previous EV charging research with platform economics research.

Firstly, this thesis has verified the usefulness of multi-sided platform (MSP) concepts for studying EV charging networks. Understanding these networks as MSP's shifts the focus in EV charging research from the technical oriented to a more systemic market approach, taking into account factors outside the technical limitations, e.g. legal and informational instruments. The path with a more business focus was laid out by San Roman et al. (2011), but not previously extended to information systems science.

Secondly, this thesis has identified the current state of the industry. Following the development phases suggested by San Roman et al. (2011), the industry is currently in the second development phase, with a third, long-term phase still ahead.

Thirdly, studying EV charging networks as MSP’s can help information systems science researchers draw analogies to other emerging industries. An EV charging network can be perceived as an Internet of things (IoT) platform, as it is a network of physical devices embedded with software and network connectivity (Atzori et al., 2010).

Overall EV charging networks should be studied more thoroughly due to their growing importance in supporting low emission transportation.

6.3 Managerial implications

The findings of this study help decisions makers to focus their efforts when developing services for EV charging. There are implications for both strategic decisions and operational activities.

Firstly, EV charging networks should focus on acquiring as much charging points as possible. This could be achieved e.g. with a skewed pricing scheme, like suggested by Caillaud & Jullien (2003). However, it should be noted that based on the findings EV charging networks do not encounter chicken-and-egg problems as network effects towards EV drivers were insignificant. Thus, EV charging networks should only focus on getting the chickens.

Secondly, in service development and marketing, EV charging networks should focus on building and communicating a smooth, efficient and reliable user experience. They should focus on doing less better and making user experience as minimized as possible on both sides. The charging network is valuable to both sides when the service works reliably with minimal input.

Thirdly, decisions makers can utilize multi-sided platform concepts in their performance metrics and strategic decision making. For example, homing is a clear indicator on how well the network serves EV drivers.

Overall EV charging network decision makers should understand that EV charging is not something anyone wants to do, but rather a mundane task that has to be taken care of. This notion should affect every part of an EV charging business.

6.4 Limitations of the study

The research conducted for this thesis has its obvious limits. They are related to the novelty of the research area and to the data gathered for the empirical analysis.

Firstly, the novelty of the industry meant that the academic background for the research was somewhat scattered. Previous EV charging research had mostly a strict technical focus, even when they discussed the economics of the industry. Only a handful of studies had relevance for this thesis. Also, platform economics research had not previously been applied in the context of EV charging, meaning the analysis in this thesis relied heavily on theories emerged in industries that differ significantly.

Secondly, the data used for empirical analysis was suboptimal. Even though single case studies can be justified (Yin, 2009), generalizations should be viewed cautiously. Since EV charging industry is relatively new, most participant CPO's were inexperienced on the subject. It is easy to argue that their opinions about the networks might differ significantly after a few years. At the same time EV drivers were somewhat experienced, but their role should also be questioned. As EV's had only a 2 % market share in Finland at the point of the study (EAFO, 2017b), the participant EV drivers were early adopters, and their opinions might differ significantly from the mass market.

Finally, it should be noted that as the industry is still emerging, it is not clear if a multi-sided platform model will actually be an appropriate business model or not. There are various competing approaches, and an MSP approach might become irrelevant in the next few years.

6.5 Suggestions for future research

As stated previously, this thesis opens a new research stream. EV charging networks can be studied in various ways by utilizing existing platform economics concepts from information systems research. In addition, the findings in this thesis suggest four future research areas.

Firstly, the findings in this thesis suggest the importance of designing boundary resources and platform architecture to maximize efficiency. However, it is not clear how this can be achieved in practice. Thus, there is a need to conduct research on the user experience of an EV charging network to understand the correct design principals.

Secondly, the limitations of this study suggest that there is a need to conduct similar research with more extensive data. This could be approached by conducting more single case studies with other networks and also in other geographic areas, or even further conducting a multiple case study to increase robustness of the results.

Thirdly, the findings in this study do not indicate the intensity of the impact by various factors on the value for participants. Thus, there is a need to conduct quantitative research to further understand the relative importance of different factors.

Fourthly, the findings in this study, both theoretical and empirical, suggest that the EV charging industry is evolving significantly in the years to come. The predicted growth in the number of EV's is likely to change network dynamics, so a longitudinal study can be justified. Roaming is likely to be a significant part in the ecosystem, and its impact on EV charging network dynamics should be studied. V2G services for the energy system are also likely to affect charging networks as they add a new side to the platform, and their impact should become a central topic in future studies.

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Appendix A: Interview guide

I. Introducing the research project and the interview

- Introducing the interviewer
- Introducing the case study
- Introducing core concepts of the study
- Introducing the semi-structured interview concept; *there is no need for a survey-like question-answer format, and discussing any issues the interviewee sees important outside the questions is preferable*
- Encouraging the interviewee to ask questions to clarify unclear issues
- Discussing privacy issues
- Discussing taping and taking notes

II. Introducing the interviewee

- Could you briefly introduce yourself, and if relevant, the organization you represent?

III A. Platform operator interview

Only for the EV charging network interviews

- **Platform structure**
    - Could you describe the service you are offering?
    - What are you offering to EV drivers? Why?
    - What are you offering to charging point owners? Why?
    - What kind of interactions are you enabling between the EV drivers and the charging point owners? Why?
- **Platform characteristics**
    - How does getting more EV drivers as customers affect the value of the service to charging point owners and vice versa? Why?
    - Are EV drivers and charging point owners using other similar services simultaneously with your service? Why?

- **Platform decisions**
    - What is your pricing model for EV drivers and for charging point owners? Why?
    - How do you regulate access to the service for EV drivers and for charging point owners? Why?
    - How do you regulate interactions between EV drivers and charging point owners? Why?
    - How open and modular is the service for EV drivers and for charging point owner? Why?
- **Platform value**
    - What are the key factors affecting the value of the service for EV drivers and charging point owners? Why?
    - How does pricing affect the value of the service for participants? Why?
    - How do the governance rules [described earlier] affect? Why?
    - How does the openness and modularity of the service affect? Why?

III B. EV drivers and charging point owners

Only for the EV driver and charging point owner interviews

- **Platform structure and characteristics**
    - Could you briefly describe the EV charging service?
    - How do you use the service typically? Why?
    - How does the change in the amount of charging points affect your interest towards the service? Why?
    - How does the change in the amount of EV drivers affect your interest towards the service? Why?
    - Are you using other similar services simultaneously? Why?
- **Platform value**
    - What are the most important factors that affect the value of the service for you? Why?
    - How does pricing affect? Why?
    - How does the lack of information affect? Why?

  - How does the platform's possibility to control charging events affect? Why?
  - How does standardization of the service affect? Why?

IV. Conclusion

- Discussing any other topics on the interviewee's mind
- Thanking for participation
- Asking about contacting about further questions
- Informing how the project continues and how participants can access the final report

Appendix B: Interview details

Interviewee	Position	Code	Interview date	Interview length
1	EV charging network support	EVCN 1	22.8.2017	73 min
2	EV charging network sales	EVCN 2	29.8.2017	81 min
3	EV driver	EVD 1	4.9.2017	48 min
4	EV driver	EVD 2	4.9.2017	44 min
5	EV driver	EVD 3	5.9.2017	43 min
6	EV driver	EVD 4	5.9.2017	50 min
7	EV driver	EVD 5	6.9.2017	55 min
8	EV driver	EVD 6	7.9.2017	35 min
9	Project Manager	CPO 1	12.9.2017	48 min
10	Technical Manager	CPO 2	13.9.2017	31 min
11	Development Director	CPO 3	2.10.2017	28 min
12	Technical Manager	CPO 4	4.10.2017	45 min